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THE
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PROGRESS IN 1912

THAT the year 1912 has been unusual in many respects will be evident from a perusal of the contributions appearing under this heading on the following pages. These brief reviews of progress represent the personal impressions of over a score of men, each of whom is in daily contact with the subject he discusses. Each has presented in his own way those developments which he considers important and of general interest. While it is not claimed that this method of presentation is ideal or that the whole field has been covered, it does give a great variety of view points, from men who are eminently qualified to speak regarding their own special lines of work, which could hardly be secured in any other manner.

A GENERAL VIEW OF THE ELECTRICAL INDUSTRY

H P. DAVIS

THE most striking development in the electrical industry during the past year has been the unparalleled expansion and activity which has occurred in the business. In fact, the beginning and end of the year show an entire reversal in these conditions. The year commenced in a period of almost complete manufacturing stagnation and ends in a period of record-breaking commercial demand and manufacturing activity. The problems which such a sudden expansion and accumulation of business impose on the manufacturer have, therefore, been those of works organization and production rather than those of apparatus development.

Periods of business depression such as existed prior to the past year, drive the manufacturer close to a starvation basis as regards materials and stocks, and the working force to a bare skeleton of the organization required for such high pressure conditions as are now being experienced. To build up a manufacturing organization and to provide stocks to meet the demands of production exceeding anything previously known, all in the space of a few months, is a proposition of no mean magnitude, but in addition the demands of the past year have been more than ordinarily severe because the selling price of electrical apparatus has never been as low as during the early part of the year. Business so taken has imposed the closest scrutiny and attention to manufacturing costs.

This condition has forced many manufacturers to give careful attention and close study to questions of conservation and efficiency as relating to manufacturing organization and production in a way never called for before. The past year has been especially pronounced in this respect and the study and application of the science of management has been so widespread and the interest in it so active that it has made marked progress, until as a matter of fact almost every up-to-date and well-managed business has introduced more or less of these principles and practices. It is a natural consequence, considering the nature of the electrical industry and the training of the men connected with it, that these doctrines should interest them, based as they are fundamentally on scientific and analytical methods, and it is not difficult to foresee that with their introduction very far-reaching results are likely to occur, especially as the character of the work and the problems presented appeal to the trained engineering mind. It is plain that an entirely new field of engineering endeavor, presenting new opportunities for the engineer and the engineering student, has been opened. As this field develops and the principles of this science become established, scientifically and specially trained engineers will become necessary in the executive work of the shop side of all industrial organizations.

Much has been said and written regarding the doctrine of conservation which, as it is most popularly presented, has to do mainly with natural resources; but we are now recognizing in the industrial fields that it is equally as important in its application to human effort and property. Labor saving machinery is so familiar to us that we accept it as the proper order of things, as we should; now, if the same character of study analysis and invention can be applied to the saving of effort in pure labor operation, great economic developments will result. Waste of time, effort and resources will soon become the emblem of bad and wasteful management.

No one becomes proficient in pastimes or serious occupations without constant application and competent instruction. The more able and experienced the instructor, the greater the possibilities for efficiency in the one being taught. We are all familiar from childhood with this order of things. Knowledge is acquired by study, experience and the teaching of others, but it is not until recently that this has been recognized as desirable and necessary in promoting efficiency in industrial operations, and the importance of organized teaching of workers by specialists been fully appreciated. Coupled with it is the recognition of the necessity for careful planning and scheduling, and last and most important, the close study by experienced and competent experts of ways and means to perform an operation or task in the most economical and efficient manner, and when this is developed to teach it to all of the workers. More and more is it being recognized, as a necessary part of up-to-date industrial development and activity, that it is important to have systems of study, education and instruction in which everything is done according to pre-arranged plans so carefully worked out as to conserve and control to the greatest extent the materials of construction, the use of equipment and the time and effort of the workers. The immediate results will be methodical manufacturing accuracy in setting and meeting deliveries, and lower costs.

Progress is demanding efficiency and with the degree of its attainment in the industrial world there will result mutual benefit to employee and employer, not only in general financial returns accruing to each, but in the advancement of industrial education and development, leading to better management, more economical production, pleasanter and more healthful surroundings for all, and with closer harmony and coöperation between the employee and the employer.

THE ELECTRICAL INDUSTRY IN GREAT BRITAIN

J. S. PECK

IN spite of the great coal miners' strike, 1912 was a prosperous year for almost all classes of British industries. Great activity in the steel, shipbuilding, textile and other trades was naturally reflected in the electrical industry, and the past year was, relatively speaking, a very prosperous one for the electrical manufacturing companies.

Power Supply Companies—The electrical power supply undertakings, which are as a rule controlled by the municipalities, have been trying to increase their motor loads, with very satisfactory results. As this load has increased, load factors have improved, and very attractive rates for power supply are being offered. This development on the part of the power companies has created a large demand for generating and converting machinery, as well as for motors and control apparatus; while on the other hand the demand for apparatus for isolated plants has been steadily decreasing, except for export trade. One noticeable feature has been the rapid increase in the size of generating units. Stations which a few years ago were laid out for units of 1 500 to 3 000 kilowatts are now ordering units of 5 000 to 10 000 kilowatts capacity, and the city of Manchester has just ordered a 15 000 kilowatt unit.

Turbo-generator Sets—The impulse type of turbine appears to be a strong favorite, but many machines of the pure Parsons type and of the disc and drum (combined Curtis and Parsons) type are still being sold. While the great bulk of the business has been in alternating-current sets, there has been a very considerable demand for direct-current sets, and machines of moderate size, when fitted with radial commutators, have operated very successfully. The favorite size appears to be 500 kilowatts, running at 2 500 r.p.m.

Rotary Converters—The rotary converter, against which a strong prejudice existed for so long in Great Britain, is now being almost universally adopted, while motor-generator sets are seldom specified except for very special conditions. Many of the municipalities supply both traction and lighting from the same station, so that a very large voltage range is required on the rotary converter. For this service, the converter fitted with a series booster is almost always used.

Electric Traction—Practically all of the large cities of Great Britain own their own tramway systems, and as these are being extended very slowly there has been little tramway business for several years past, but the great increase in business following upon the electrification of certain suburban railway lines has brought prominently before railway directors the many advantages of this system of propulsion, and it seems reasonably certain that a large amount of suburban electrification will be done during the next few years. The London & Northwestern, London & Southwestern, London, Brighton & South Coast and the London & Tilbury are all proposing to electrify their suburban service as rapidly as possible. In addition, the Northeastern Railway, which electrified some of its suburban lines around Newcastle several years ago, is about to electrify eighteen miles of main line for heavy freight traffic. Fifteen hundred volts, direct current, will be used for this service, but for most of the suburban lines about London, 600 volts will be used. Several small installations of the trackless trolley system have been made and, while satisfactory operation is obtained, it does not appear that this system will ever be able to compete successfully with the electric tramway, except under very exceptional conditions.

Magnetic Brakes—A considerable and rapidly growing export trade is being done with the Continent in magnetic brakes for electric cars. In Great Britain, where thousands of magnetic brakes are in successful use, the track magnet is usually coupled to the wheel brake shoes, so that the drag of the magnets along the rail also applies the wheel shoes, but on the Continent the wheel shoe attachment is omitted, and only the friction between rail and magnet is depended upon for braking purposes. To meet this requirement, very powerful though light weight magnets have been developed. The largest of these, weighing less than 500 lbs., gives a vertical pull of 10 000 to 13 000 lbs. Four of them are sufficient to stop the heaviest car in an extremely short distance. In certain cases these magnets are applied for use as emergency brakes, in addition to the usual air brake equipment. In many cases the magnets are supplied with two windings, one for trolley current and the other for excitation from the motors acting as generators.

Electrification of Textile Factories—In the textile trade the individual driving of looms is coming into great favor, and thousands of motors are being sold for this purpose. The individual drive for spinning machines is not generally recommended, and group driving seems generally preferred. While there is an increasing demand for electric motors for group driving, the wholesale electrification of spinning mills has not yet begun.

Switchboards—The very stringent regulations made by the Government departments for regulating the use of electricity in mines have brought about marked improvements in the mechanical design of switchboards and control apparatus. Iron clad switchboards are used for all classes of service, not only underground, but in mills, factories, and wherever dust-proof and fool-proof apparatus is required.

Electric Heating and Cooking—The power companies are making a strong effort to attract this class of business, and are offering very low rates for current. One penny (2c) per kilowatt-hour, appears to be the prevailing charge, but in several cities a rate of ½ penny (1c) is offered. With the inducement of the low rates, it seems certain that an enormous development will come about in this particular business.

RECENT CANADIAN DEVELOPMENTS

N. S. BRADEN

THE year 1912 not only saw the completion of important engineering works and the continuance of other undertakings, but also the inauguration of very large new enterprises.

In the coal fields of the Maritime Provinces important applications have been made for the electrical drive of various machines used in coal mining operations, which include the installation of large turbo-generator plants and distribution systems throughout the district to the various mine openings for operating air compressors, ventilating fans, centrifugal pumps, water hoists, etc.

In the Province of Quebec work has begun on the development of the water power at Cedar Rapids in the St. Lawrence River, which development, when completed, will rival the largest installations at Niagara. At Shawinigan Falls, in the same Province, orders have been placed for additional units of 15 000 k.v.a. in generators of the water-wheel type. Each of these plants will supply power for the city of Montreal, and the amount of energy which the city requires is only one of the many evidences of the wonderful growth of that city, and this growth is also responsible for a very important undertaking in connection with the transportation facilities at Montreal, viz., the building of a double track tunnel three and one-quarter miles long under Mount Royal, by the Canadian Northern Railway, which will give it access to the heart of the city for its passenger terminal. This tunnel will be electrically equipped for freight and passenger as well as suburban traffic.

In the Chicoutimi district of Quebec large water powers are being developed for use in the paper and pulp industries, and the same is also true in other Provinces of the Dominion where extensive timber tracts adjacent to fine water powers make ideal conditions for the manufacture of pulp and paper.

In Ontario the Niagara development has proceeded with the enlargement of all the plants on the Canadian side. The extensions and development of the distributing system of the Hydro-electric Commission of Ontario has been one of the important and striking features of the year just passed; these lines now serve nearly one hundred cities, towns and villages, and it is gratifying to know that the operation of the high tension lines at 110 000 volts has been remarkably free from service interruptions, a feature which speaks highly not only for the design of the equipment supplied but for the engineering displayed in the design of the transmission line and distributing system.

In central Ontario the series of large hydro-electric developments in the Trent Valley District have been very successful, and provide cheap power to a section heretofore neglected. Many large towns and villages are embraced within the distributing system. One of the most important industrial applications of electric motors is an installation which is now being made by the Steel Company of Canada at their Hamilton Works, which will consist of complete electrical drive for their new blooming mill, billet mill and rod mill. Every machine will be driven by motors, from a ten horse-power constant speed motor to the 8 000 horse-power reversing blooming mill motor. The power for this installation will be supplied by one of the large hydro-electric power companies, through suitable fly-wheel motor-generator sets of the latest design.

At Sault Ste. Marie, Ontario, large steel, rail and pulp mills are being electrically driven by large motors of either the reversible or constant speed types, the energy being derived mainly from large blast furnace gas engine generator units.

In connection with the handling of coal which is shipped into the Northwest through the Lake Superior ports in large quantities, it is of interest to know that these coal handling plants are electrically equipped, using either fly-wheel motor-generator sets, or equalizing generators with fly-wheels, the operation of which has been most successful, and such applications were the first to be used in this country.

In the three prairie provinces of Manitoba, Saskatchewan and Alberta, the growth of electric light and power plants has been rapid and continuous, and all the larger towns are now either equipped with electric railways or installing the same, this being a truly remarkable showing for towns which, a few years ago, were mere villages.

In the far western province of British Columbia the past year has witnessed remarkable growth in electric railways in Vancouver and suburbs, and in Victoria, on Vancouver Island, and the enlargement of power plants on an extensive scale to provide for the increased growth of these cities and, in addition, the important water power development at Stave Lake, B. C., has been put in successful operation, supplying a large amount of power to Vancouver and vicinity. British Columbia is also to have the first 1 200 volt electric railway equipment in Canada, which is now being installed on a road 52 miles in length, extending from New Westminster to Chilliwack. To indicate the business which is offering, it is sufficient to say that this road is now operating with three-car trains four times a day in each direction, and in addition is installing several fifty ton 1 200 volt locomotives to handle the freight business.

Vancouver Island is attracting much attention in connection with its material development, particularly of its water power and coal mines. One of the leading collieries is installing a large hydro-electric plant as well as the most modern type of electric hoists and appliances for deep mining. When finished it will be one of the most complete electrically equipped mining properties in the world.

Outside of the electrical development in Canada, there is a wonderful growth of the steam railroads and the country is now traversed by one transcontinental railroad, the second is nearing completion and the third is also building. Each of these roads will have its termini on the extreme Eastern and Western coasts, and at least one road will connect with a Government railway now building to the Western shore of Hudson Bay.

Another gigantic undertaking is the beginning of the enlargement of the Welland Canal, at a cost of $45 000 000, to enable large lake vessels to proceed between Lakes Erie and Ontario.

In the gold and silver mining districts of Northern Ontario extensive development of available water powers has been completed, and electrical energy is now used by all the large mining companies.

THE MEXICAN SITUATION

C. V. ALLEN

IN considering this subject from all sides, as well as electrically, it should be borne in mind that Mexico has but recently completed her second year of revolutionary troubles. The fact that there is no head, or organization, among the revolutionists, renders no easy solution to the Government, who must now deal with a multitude of scattered bandits, whose sole object is to loot and plunder.

The wealth of Mexico is in its haciendas and mines, both located in remote places most difficult to protect from molestations with the small Federal military forces available. The mines represent by far the greatest wealth of the country, and are the largest users of machinery, electrical included. It is this industry which has created the large demand for electrical power, so readily obtainable from the natural water powers of the country.

With copper and silver at almost record high prices during these last two years, Mexico should have gone ahead with enormous strides; and the electrical industries would have reaped their share. As it is, those companies which have not been actually interfered with cannot see their way clear to develop their mines or buy new equipments without some assurance of the outcome of the revolution and a stable government.

It is remarkable to note the determination shown in the continuing of operations, and the few actual serious interruptions that have occurred under the trying conditions of the last two years. The power companies' salvation lies in keeping voltage on their circuits for, although it is easy for a peon to climb a pole and cut a telephone line with a "machete," he cuts his last wire when he attacks the power lines farther up. One power house was raided on two different nights, the Americans in charge escaping each time by jumping from a second-story window, leaving the plant to be run by the native forces for many days. At this writing, this same plant is shut down entirely, the native operators being molested beyond endurance.

The largest system in the country has been but little molested, aside from threats if money is not forthcoming for the rebels' maintenance. In spite of conditions, some of the more extensive work already started when the revolution began is being continued, and some new work has since been undertaken.

Considerable progress has been made at the Tuxpango Falls development. About 30 000 horse-power is available here; the first installation having a capacity of about 12 000 kilowatts. This power plant is located between Puebla and Vera Cruz, and will transmit to both cities, as both electric plants are owned by the same company.

The Conchas River proposition, in the State of Chihuahua, is controlled by the same people, this plant comprising about 40 000 horse-power. Work has been somewhat interrupted, but is now progressing. The power company in Guadalajara is overhauling its sub-stations, and installing a large switchboard, both for high and low tension control. At Necaxa, where power for the Mexican Light & Power Company is being generated, enormous tunnel developments are being made to bring water from other watersheds to their reservoir. A great deal of money is being spent in this work, and it has progressed steadily. A mining company in Zacatecas recently purchased a 1 000 k.v.a. steam turbine outfit, with complete motor equipment; and in Oaxaca a 625 k.v.a. steam turbine is being installed by another mining company.

In the North, large irrigation projects are in hand, one providing for a million acres to be irrigated, with a power house of 4 000 horse-power, and pumps of 15 000 litres per second capacity. The Mexican Tramway Company is extending its railway circuits, to take in interurban traffic from Mexico City to Puebla and Toluca.

All of this shows that work has by no means stopped during the recent troubles. Mexico has encountered but a temporary setback with its revolution, and cannot fail to recover, due to its great wealth of natural resources. The Americans alone have invested over a billion dollars in Mexico, comprising: $644 000 000 in railway stocks and bonds; $250 000 000 in mines and smelters; $223-000 000 in national bonds; $15 000 000 in the oil business, with the same in rubber; $9 600 000 in factories, and $760,000 in tramways, power and electric plants, etc. In all of those mentioned, except electric plants, the Americans lead all other nations combined, even including Mexico herself, in capital invested. England leads all other countries in investments in electric plants by many millions; Mexico herself owning between five and six million. The Mexican Light, Power & Traction Company, with its present load of about 50 000 horse-power, transmitting power 171 miles at 85 000 volts (the highest voltage in Mexico), is owned by English capital. The large interests of Lord Cawdray represent the bulk of England's electrical holdings in this country.

All electrical apparatus and machinery must be imported into Mexico, as no factories exist as yet, aside from a small carbon filament lamp factory, with rumors of a tungsten lamp factory to be started soon by an American manufacturer.

A law to increase all duties twenty percent is now before Congress. The imports into Mexico from the United States in 1911 amounted to 55.8 percent of the total (or $53 000 000); Germany came next with $12 000 000; Great Britain, $11 000 000, and France, $8 000 000, etc. In 1912, Mexico exported $92 000 000 of gold, silver and other mineral products, with but $2 220 000 of manufactured articles. The trade of the United States with Mexico has been trebled in the last ten years.

It is doubtful if any other country has a greater variety of electrical machinery of different makes than Mexico. So far, Chinese and Japanese competition has not been felt. But "made in Germany" is in strong and increasing evidence. Germany caught up with, and displaced England, in its place in exports into Mexico, in 1906, and has greatly increased its representatives in Mexico since. It is safe to say that the business done by Germany with Mexico, in hydro-electric, gas-electric, and other general electrical machinery, is greater in proportion than the ratio referred to above with reference to total imports.

Mexico is an old country, it is true, but quite new so far as development is concerned, as is evidenced by comparing its exports and imports. The country is too rich in mineral and agricultural resources for the present unrest to continue long, before political confidence is restored. The American of means knows Europe, and even the Orient better than he does his neighbor, Mexico, with the result that he invests abroad rather than in Mexico, where three or four days by train would take him to his property. The geographical location of Mexico, together with a bank rate of interest of 8 percent, and its undeveloped state, makes it the most natural overflow market for capital from the States. Then, why is its development left to foreign powers, who will surely buy their machinery and needed materials at home, thus causing the loss of a good customer within easy reach of the manufacturers in the States? The American merchant and manufacturer may have enough to do at home; if not, he first seeks export business with the country which conducts business most in line with his methods. This does not take him to Mexico. The American's business failure in Mexico can almost always be traced to lack of conformation with local customs and insufficient study of the people. He rather expects (and often demands) that Mexicans change to his ways—and quickly, too. That is where the Spanish, French and Germans score. Patience and tact are two qualifications the American should have in going to Mexico. Otherwise he will find himself meeting the fate of Kipling's hero, who "tried to hurry the East." If he has the Spanish language at his command, so much the better, as he will find it extremely useful in business.

RECENT DEVELOPMENTS IN AIR BRAKE PRACTICE

S. W. DUDLEY

RECENTLY, and especially during the past year or two, there has been a growing change in sentiment on the part of those directly connected with the operation of both steam and electric railroads toward the engineering and economic importance of the train control apparatus. Instead of being an inconvenient and but little understood safety device, the power brake has gradually come to be recognized as a possible time saver and so a dividend earning asset capable of being developed to an indefinite degree. This change in attitude was largely contributed to by the increasingly severe traffic requirements of congested districts in and near large centers of population and long hauls. On the part of the manufacturer, closely in touch with the trend of development throughout the country, this rapid and general expansion was early recognized and its significance realized. This resulted in a period of unprecedented activity, culminating in the perfection of new and improved apparatus which would satisfy the most exacting requirements throughout a wide range of service—marked by the single car or motor-trailer city service on the one hand and the high speed interurban multiple-unit train service or electric locomotive service on the other hand.

The extent and permanency of these developments have been evidenced by the extended introduction of the improved types of equipment during the past year. A notable example is the adoption of an especially light and simple straight air brake equipment with automatic emergency features, known as the "featherweight" equipment, as practically the standard type of apparatus for light traction service. This equipment was especially designed to meet the limitations of space, weight and simplicity in connection with cars of the double deck, center entrance and other similar types of modern light city street cars operating normally in single units or with but one trailer car. This apparatus has proved to be readily adaptable to these unusual requirements and has been received with much favorable attention.

Closely allied to this equipment is a special adaptation of the apparatus to permit the amount of braking power to be automatically proportioned to the different loads carried by the car at different times. While this form of apparatus was developed primarily for certain specific requirements, the fact that such a form of mechanism was found desirable is a significant indication of the advanced state of the art and the engineering consideration which the situation has commanded, both on the part of the manufacturer and the users of such apparatus.

The development of these equipments, designed for especially light service, has been accompanied by a corresponding improvement in the detail apparatus. As an example may be mentioned the development of a special line of motor driven air compressors of light weight and simplified design, in which particular attention has been given to the improvement of mechanical details tending toward a higher mechanical and electrical efficiency, simplicity and reliability under severe conditions.

A further development in motor-driven air compressors has been brought about by the requirements of two-voltage service. This condition has been provided for in three ways, namely, by using a double commutator motor for the air compressor, the motor having separate windings, suitably arranged or connected for the two voltages to be employed; by driving the compressor direct by means of a clutch from the shaft of the dynamotor supplied with the electrical equipment to take care of lights and other accessory apparatus and by having two complete compressors mounted on the same bed plate and mechanically connected (to insure equalization) by a multiple disc clutch, the motors being designed to run in multiple on the low voltage and in series on the high voltage. Operating and installation conditions determine which of these arrangements will be preferable in any given case, it being usually found that the dynamotor compressor combinations are most economical, both of space and power, and in general most attractive.

In the field of heavier traction service the advantages of the electro-pneumatic brake control have been receiving more and more attention. The demands in this field have been so intense in certain localities and have been characterized by such well defined local requirements that in almost every case each problem has had its own highly specialized and determining peculiarities. Consequently the successive stages in the development of the electro-pneumatic brake have been more in the nature of the individual applications of the same general principles than the general adoption of a uniform standard arrangement of apparatus. The equipment of the New York, Westchester & Boston Railroad is a typical instance. In this case the type of the cars, truck design, operative requirements and future posibilities all present such marked, novel features as to require a special study and the evolution of a complete equipment which, from operating valves and automatic mechanisms to foundation brake gear design, should meet these requirements most efficiently. The solution was the adaptation of a standard form of electro-pneumatic control to the type of pneumatic valve mechanism which had already been perfected for use on the heaviest types of steam railroad passenger car equipment. The results have amply justified the confidences of the manufacturers and the expectation of the railroad regarding the all around efficiency of this installation for this particular service.

As a result of the above mentioned tendencies toward specialization in individual electro-pneumatic installations it has been realized that the logical solution of the problem of meeting widely diversified requirements without undue multiplication of special details would be to develop a composite equipment having a simple form of triple valve as a base, capable of expansion to meet the most complicated requirements by the addition of such unit parts as needed in each individual case. This has been successfully worked out and opens up a wide and promising engineering and commercial field.

The considerable weight concentrated on the motor axle of the New York, Westchester & Boston cars suggested the advisability of using two brake shoes per wheel (clasp brake arrangement) instead of the single brake shoe per wheel almost universally used in this country until recently. The design employed on these cars presents several novel features arising from the type of truck construction employed. The installation marks a distinct advance in efficient brake rigging arrangements for modern service requirements—an engineering improvement in which American practice generally has lagged far behind that of English and Continental practice, where the superior advantages of the "clasp brake" have been quite generally recognized and used for years, even in much less severe service than is common in this country.

The growing length and weight of trains in steam road service and the increasing demand for convenience and smoothness of operation, as well as reliability, in taxing to the limit the capacity of the purely pneumatic brake, have naturally directed attention to the advantages of the electro-pneumatic form of control. Its successful operation in such service as that of the New York, Westchester & Boston, the Boston Elevated, the New York Interborough (Subway division), the Hudson & Manhattan, the Philadelphia

Rapid Transit Company, and elsewhere, has fully demonstrated the superiority of this over other forms of brake control for train service operation of any character and its future extension to steam railroad service is a logical consequence. The preliminary and developmental stages, already a matter of history in electric railway service, enable this advanced step to be taken with apparatus already fully developed instead of involving experimentation with new or untried principles.

Progress in automatic connectors between cars has been continued by the incorporation of an automatic electric coupler in the automatic car and air coupler. By this improvement a still further saving in time of making up trains and drilling cars is effected and the safety and efficiency of the service materially advanced.

A similar progress has been made in the perfection of details for safeguarding and increasing the efficiency of the service generally. Examples are the introduction of automatic interlocking mechanisms, whereby the motor control circuit remains open and the car cannot be started until the air brake mechanism is in the proper condition for operation and a sufficient air pressure accumulated to insure safety in case of emergency; improved "dead man's" valves; sanding devices and automatic control of auxiliary devices, such as door openers, gongs, fenders, trolley, etc., all interlocked with and synchronous with certain operations of the air brake.

Possibly one of the most encouraging tendencies of the past year has been the increased attention on the part of the users of air brakes to the improved service and economy of operation which can be accomplished by a closer inspection, better maintenance and generally higher standards in the care and use of the apparatus already in service. This has been evidenced in greater expenditures for test apparatus, enlargement of facilities and organization for maintenance work and a free interchange of ideas and adoption of new and improved methods along broad and permanent lines. The often repeated truism that inadequate apparatus closely inspected, well maintained and intelligently used, is better than the best if only poorly maintained and not utilized to its fullest capacity, is gradually coming to be generally recognized and the resultant improvements have always justified whatever steps have been taken in this direction.

Broadly speaking, the progress of the past year has been systematic, following logically the advancements of preceding years in response to corresponding increases in the requirements of the service which had to be satisfied. Such progress is an evidence of a normal condition in any department of engineering practice and is especially encouraging in the present instance, both because it indicates the continued healthy advance of the art and as an assurance of definite efforts towards a high degree of excellence in the service rendered the users of air brake apparatus and the public in general.

IMPROVEMENTS IN INCANDESCENT LAMPS

B. F. FISHER, Jr.

THE past year has seen more startling changes and radical improvements in incandescent lamps than any one year since the introduction of the tungsten filament lamp. The carbon filament lamp which has been the foundation of our enormous central station lighting business has passed its day of usefulness and has been relegated with the tantalum lamp to the oblivion of the obsolete classes.

Metallized filament lamps have enjoyed a day of popular favor but as the year draws to a close they are little more than holding their own, as the tungsten filament lamps are gaining so rapidly in popularity.

Tungsten filament lamps are now used in all classes of service, and are giving a good account of themselves even in the most severe service. From present indications the time when tungsten filament lamps will be the only lamps in use is not very distant. This sudden increase in the use and demand for tungsten lamps can be accounted for in several ways. The lamp-using public has at last realized that the idea of extreme fragility of tungsten lamps has remained with us too long. They have also found that present lamps are not as fragile as those formerly made and that with any reasonable care there is little risk of breakage.

The improvements in manufacture during the past year have made possible two radical reductions in price, so that now the price of tungsten filament lamps is not high when compared with other classes of lamps.

The average life of tungsten filament lamps has been steadily increased; at first the life was 500 hours; this was increased to 800 hours and is now given as 1 000 hours. This increase in life indicated radical improvements in the lamp, but it does not begin to indicate the improvements of the last year, during which the lamps gave an average life of from 100 to 200 percent in excess of the guaranteed life. To keep the actual lamp life somewhat commensurate with the guarantees, it has been necessary to increase the efficiency of the lamps twice during the past year, which increases in efficiency also indicate radical improvements. The efficiency of the 25 watt lamp has been increased from 1.31 to 1.17 watts per candle, which is an increase of 12 percent, thus giving 12 percent more light for the same expenditure of energy, with an average life which continues to exceed that guaranteed. These increases in efficiency in order to keep the life of the lamps commensurate with the life guarantee have always followed improvements in the lamps and have never anticipated them, so that it should be expected that at the present high efficiency the life performance of the lamps themselves will far exceed the guaranteed performance.

The most radical change since the introduction of the tungsten filament lamp has taken place this year. It has been generally known that tungsten lamps continue to burn for a long period after they become unserviceable, due to blackening, and it has been the aim of the lamp manufacturers to make this life available for good service by preventing the blackening. It has been found that by introducing a chemical within the bulb the appearance of blackening could be postponed until practically the ultimate life of the lamp had been reached. This introducing of a chemical to prevent blackening is the most important invention since the introduction of the tungsten lamp.

In addition to these improvements the ten watt lamp for 100 to 130 volts service has been developed, thus furnishing a lamp suitable for decorative work in residential service as well as for sign service. This lamp makes the list of tungsten lamps for 100 to 130 volt service complete from 10 to 500 watts, which condition has never been possible with any other class of lamps.

DEVELOPMENTS IN POWER GENERATING APPARATUS

H. A. RAPELYE

THE year 1912 has witnessed the successful working out, on a large scale, of many ideas in power generation which a year ago were scarcely beyond the experimental stage. The steam turbine, as has been the case for several years past, offers the best example of this. Two years ago in referring to a large turbine, a unit of from 7 500 to 10 000 kilowatts would have been understood. This size is now so thoroughly standardized that to-day the term "large turbine" would be much more apt to refer to a unit of 20 000 kilowatts capacity, or greater. There are contemplated in this country at the present time several stations involving the use of complete expansion machines of 25 000 or 30 000 kilowatts capacity at their economic rating. The steam turbine has also gone forward in its various other forms as rapidly as the complete expansion machines referred to above. For instance, the automatic bleeder turbine, a comparatively recent type, has been built in sizes up to 4 000 kilowatts, normal capacity, and it is quite probable that even larger machines than this will soon be seen in commercial service. Low pressure and mixed flow turbines, while not being built in large sizes, with one or two notable exceptions, are finding a broader field of application as the possibilities of their use become more generally known. However, two years ago it was not unusual to hear prophecies that the steam power station of the future would consist of reciprocating engines operating with atmospheric back pressure, expansion of the steam being completed in low pressure turbines. In the light of later exprience, this idea seems to have been generally abandoned, and with good cause, since the complete expansion turbine as built today offers an incomparably superior outfit from every point of view.

There is noticeable at the present time a more general appreciation of the economies possible with non-condensing turbines, where designed for such service. For instance, it is possible to obtain a higher efficiency ratio with such a machine than with one designed for completely expanding the steam. Its performance is, therefore, about equal to that of the best non-condensing reciprocating engines, and when the lower cost of installation and the superior operating characteristics are taken into consideration, the choice of the turbine is quite clearly indicated.

Where the output of the turbine, whether complete expansion, low pressure or non-condensing, is desired in the form of direct current, engineering opinion quite generally inclines toward the use of reduction gearing, the most modern and approved type of which has seen commercial service for about two years, in addition to the original exhaustive experimental work. Two 3 500 kilowatt direct-current units of this type, which are the largest yet constructed, have passed through tests in a most satisfactory manner and give promise of remarkable commercial results.

The broadening of the field of turbine application is particularly apparent in the case of auxiliaries. This field is so well covered at the present time that practically every operation in a power house which is not performed by motor-driven apparatus, may be handled by turbine outfits. Boiler feed pumps, forced-draft fans and condenser circulating and air pumps of the turbine-driven type, are well standardized, and their performance has been so satisfactory wherever used that there can be no question as to their superiority and their almost universal use in the future. The advances in centrifugal pump design have been such that it is almost impossible to find a pumping condition which may not be economically met by a turbine-driven outfit; and the small number of cases where this is not true is still further reduced by the development of reduction gearing of such high efficiency that the combination of the turbine and pump is made with a gain rather than a sacrifice.

Internal combustion engines of all types appear to be finding the proper level of their application. Contending with the disability of high first cost, lack of flexibility and small overload capacity, they still show marked economy where load factor and fuel costs are high. It is but fair to say that the mechanical development of this class of prime mover is very high, but it is difficult to see how the use of such equipment is justified in plants of more than 1 500 or 2 000 kilowatts capacity. There remains, of course, the field for the blast furnace gas engine, which is now fairly well established as a part of any blast furnace plant. Gas producers in connection with power work have suffered from the same causes as gas engines. The marked upward variation in the price of fuel oil has helped the producer in a very marked degree in another field, since many plants using oil in furnace work of different kinds have turned to producer gas as a fuel of more uniform and perhaps lower average cost, with the additional advantage of close heat control and somewhat more desirable flame character for a good many classes of work.

The uni-flow steam engines and small engines of the locomobile or semi-portable type, of which so much was expected by many, have rather failed to justify these expectations. It is not found that they are making inroads upon any market except that of the reciprocating steam engine, and it is generally acknowledged that this market is growing smaller with each successive year.

Condensing apparatus has seen no radical changes, except the increasing use of jet condensers of very large capacity, a field which has until recently been conceded to belong to surface equipment. The arithmetic of condensing plants is much more familiar to the engineer than it was two years ago, and this might be said to apply with almost equal truth to the designer. This being the case, and the three types of condensers—barometric, low level jet and surface—having each its own fairly well defined field of application, it is not surprising that some of the older ideas should be abandoned. The one salient development along lines of condenser practice has undoubtedly been the use of smaller amounts of surface to accomplish a given amount of condensation. This is possible simply and solely because of a better appreciation of the relation of air pressure and cooling water velocity to the rate of heat transfer.

The large steam boiler has not as yet come into its own, but may be confidently expected to do so. Those in use are justifying in a high degree the guarantees of their designers and the hopes of the engineers responsible for their installation.

There have been no particular advances in stoker practice during the year 1912, although it must be considered a distinct gain that stoker users appreciate to a larger extent that different types of stokers are necessary for fuels of widely varying character. The result of this will, of course, be the gradual elimination of unsuccessful stoker plants and the ultimate disappearance of the hand-fired plant, except in very small sizes.

PROGRESS IN RAILWAY SIGNALING

LLOYD V. LEWIS

An installation of railway signals constitutes a problem in energy distribution unique in respect to the character of its load, distributed as it is in small units along a railway line for a space of a hundred miles or more. The usual solution of the problem offers direct current with a battery at each location.

If the line is to be electrified or even paralleled by an electric road, the situation demands alternating current for the track circuits. As a result, the signal engineers of a great many roads have had occasion to become familiar with alternating-current signaling apparatus on their own lines from installations made to meet some local condition, and their study of the incidental operating economies is leading to the extensive adoption of alternating current in situations in which direct current would heretofore have been used without any question. On this account the past year has witnessed over one thousand miles of new signal construction on steam roads in which all track circuits, relays, motors and signal lamps have been energized by alternating-current power, usually obtained from one or several local lighting companies along the route, and distributed by 2 200 to 4 400 volt lines. It is interesting to note that single-phase transmission has been resorted to in almost every case, the added complication incidental to polyphase transmission more than offsetting the increase in line economy.

In a typical installation of this sort a 3 300 volt transmission line has been laid underground between tracks, the energy being obtained from a number of alternative sources. Additional insurance against power interruptions is obtained by energizing the signals at interlocking towers, which are spaced about five miles apart, by direct current obtained from storage batteries charged by mercury rectifiers from the alternating-current line. In the instance of complete failure of the alternating-current power, train movements may still be governed from tower to tower. Overhead line wires for the control of distant signals are almost entirely avoided by the use of polarized track circuits.

This activity is naturally reflected in the development of new apparatus and improvements in the direction of increased safety and economy. The most noticeable achievement is a new signal mechanism operated by a slow speed induction motor mounted at the top of the signal mast and geared directly to the semaphore, friction being minimized by the liberal use of ball and roller bearings. The signal is held in the clear position purely by induction without contact between the stationary and moving parts of the holding device. By a careful redesign, the efficiency of the induction motor type of track relay, already very economical, has been greatly increased. A highly efficient and safe track relay has been developed for electric roads using alternating-current propulsion in which a small induction motor operates a centrifuge, for actuating the relay contacts, which is so proportioned as to be inoperative by rotation at the frequency of the propulsion current. As one phase of the motor receives energy from the track and the other from a local source, an essential feature is a design of motor in which damping and not single-phase rotation is secured with the track phase short-circuited. Another interesting novelty is an alternating-current highway crossing bell without contacts, containing an oscillating form of induction motor.

A subject which has received widespread attention during the past year is that of automatic train control. Distressing accidents have occurred on lines having complete signal protection, from failure of the engine runners to see or obey signals, and it is therefore proposed to bridge the gap between the signals, which are controlled automatically by track conditions, and the brake controlling apparatus of the moving train. Automatic stops are familiar from the installations in the subways of New York, Boston, and Philadelphia, where their use has greatly safeguarded and expedited traffic under the conditions there existing. To provide for the complex conditions of the average steam road is a different matter.

It is not sufficient to place a stop device at a stop signal; the train might pass the signal at full speed, the brakes be applied, and run into the rear of another train a short distance beyond. It is not allowable to place the stop at the caution signal, as at this point no cause for stopping the train exists. The solution adopted in all cases where automatic stops have so far been installed is the overlap, i. e., two stop signals or a full block at all times in the rear of the moving train; but this requires radical changes in existing signals and decreases the permissible train spacing on the average steam road to an extent almost prohibitive. It also appears essential to provide some means for passing a stop signal in automatic territory after coming to a stop and, as well, to provide an absolute stop at an interlocking signal which may for example protect a crossover. There still remains the necessity for protecting the many situations in which a medium speed may be safe and desirable while a high speed would be a source of extreme danger.

The efforts of inventors in this field have largely been devoted to a search for a method of transmitting stop signals to a moving train in such a manner that a failure of any part of the apparatus will result in a stop. The safe alternative, to place a device on a train which will permit it to run only a certain distance, and then to transmit proceed signals to the train to keep it moving, appears to have been largely overlooked.

Cab signals, repeating the fixed signal indications within the engine cab, have been considered, but are open to the objection that their use tends to distract the engine runner's attention from outside objects and because of the probability of conflict between the indication of the fixed signal and cab signal if the latter is not continuously under the control of its source of energy. An application of the principles of wireless telegraphy offers some promise in the solution of this proposition.

Additional difficulties exist in securing sufficient flexibility in the automatic control of the brake apparatus of the train to take care of all conditions. An emergency application may be essential to stop a high speed passenger train within a reasonable distance, yet would prove a serious source of danger if applied on a hundred car freight train.

It should be borne in mind that a railway journey is an event which may be disastrously interrupted from a great number of causes, the occurrence of any one of which may be individually very remote. Automatic train control eliminates but one, namely, the failure of engine runners to obey signals. To be of value this must be accomplished without bringing in other new possible causes of accident, such as would be represented by a decrease in responsibility on the part of the engine runner or a false sense of security engendered by the stop device itself.

Up to the present time, none of the many control schemes devised have succeeded in meeting all objections in a manner convincing to railroad operating officials, but it is quite likely that the real demand which now exists will result in bringing out one or several devices in the near future, of such a character as to materially increase the safety of railway travel.

THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

F. L. HUTCHINSON,
Secretary

THE year 1912 has been one of growth, activity and progress in the American Institute of Electrical Engineers. The membership, the number of meetings held, the number of technical papers presented, the variety of subjects covered and the amount of material issued to the membership in the publications of the Institute have all had a healthy growth.

In January a modified plan of nominating officers of the Institute was inaugurated. Previously, it had been necessary to send a nomination blank to each member of the Institute, with the request that he insert the names of such members as he desired to nominate for the various offices. There was no official way in which a group of members could suggest to the membership at large the nomination of any particular member; the result was an exceedingly large scattering vote. A by-law was adopted providing that if fifty or more members suggested in writing the name of a candidate for any particular office by a specified date, these suggested names would be printed upon the nomination blank, so that the membership at large would have the advantage, when making their nominations, of having before them the names of several members who had been thus suggested. The result was a greatly increased nomination vote and a concentration of the vote upon the candidates thus nominated. One result of this method is that it enables any group of members to present the name of their candidate for any office to the entire membership on the official forms of the Institute, thereby rendering it unnecessary to issue circular letters.

In accordance with the provision of the constitution by which honorary members may be chosen from among those who have rendered acknowledged eminent service to electrical engineering, the Board of Directors, in January, elected as honorary members, Professor Andre Blondel, of Paris; C. E. L. Brown, of Baden, Switzerland; Dr. Emil A. Budde, of Berlin; Mr. Sebastian Z. de Ferranti of London, England, and Professor Antonio Pacinotti (since deceased), of Pisa, Italy. These were the first to receive the distinction of honorary membership in the Institute since 1892.

A trip to the Panama Canal for members and their guests was arranged by the Institute and a party of 110 members and guests visited the canal in January, and all were afforded unusual facilities for inspecting everything of interest.

The Institute's friendly relations with foreign electrical societies have been augmented during the year by the establishment of visiting member privileges with the societies, which will enable Institute members traveling abroad to have the privileges of membership in the foreign societies for a limited time, in return for which members of the foreign societies visiting America are accorded similar courtesies by the Institute.

Arrangements for holding an International Electrical Congress at San Francisco, in 1915, are progressing. At the request of the Institute, authority to organize such a congress was granted by the International Electrotechnical Commission at its meeting in Turin, Italy, in September, 1911, and since then the committee on organization of the Congress has been appointed by the president of the Institute.

In the month of May constitutional amendments were adopted, provided for the classification of the membership into three grades, namely, Associates, Members and Fellows, in place of the two grades, namely, Associates and Members, previously existing. Under the old classification only about ten percent of the entire membership was in the grade of Member, the remaining ninety percent, although consisting very largely of professional electrical engineers, being Associates. For four successive years committees had been appointed to study the conditions, and to recommend such changes as were deemed desirable. The result was the recommendation of the amendments which were adopted last Spring and which are now in force.

For admission to the grade of Fellow, at least ten years professional experience is required. The grade of Member retains the five years experience but does not retain the former length of time required for responsible charge of work, providing the member is qualified to take such responsibility. The requirements for the grade of Associate have not been changed and, as formerly, it is not necessary that an applicant shall be an engineer in order to be admitted to this grade.

The Edison Medal for the year 1911, which was awarded to Mr. George Westinghouse "for meritorious achievement in connection with the development of the alternating-current system for light and power," was presented to Mr. Westinghouse at the annual convention of the Institute held in Boston, in June.

The sections and branches have been unusually active. One new section was added to the list during the year, known as the Indianapolis-Lafayette Section. Six new branches have been organized: The University of California Branch, Clemson College (S. C.) Branch, Highland Park (Iowa) Branch, Lafayette College (Pa.) Branch, University of Oklahoma Branch, and the University of Virginia Branch. This brings the total number of local organizations up to 73, including both the sections and branches, the distinction being that the sections are composed principally of members of the Institute and are generally located in large cities, whereas branches are organized by members of the Institute who are professors or instructors in colleges, for the purpose of interesting the students in the work of the Institute. During the eleven months covering the period between January 1st and December 1st, the sections of the Institute have held 213 meetings and the branches 270 meetings, a total of 483.

Regular Institute meetings have been held each month except during the summer, in New York. A three day meeting devoted to the subject of "Industrial Power" was held in Pittsburgh during the last week in April; a Pacific Coast meeting was held in Portland, Ore., during the same month. An Institute meeting was also held in Schenectady on May 17th. At all of these meetings technical papers were presented and discussed.

The annual convention was held in Boston during the latter part of June, with an attendance of about 960. Fifty-seven technical papers upon a wide variety of subjects were presented. Advantage was taken of an opportunity to coöperate with other societies by holding two sessions jointly with the Illuminating Engineering Society and the Society for the Promotion of Engineering Education, at which subjects of interest to the members of the societies concerned were discussed.

Resolutions looking toward needed reforms in the American patent system, prepared by President Mershon, were adopted by the Board of Directors on November 8th, with the approval of the Public Policy and the Patent Committees. These resolutions, which have been forwarded to the members of the House and Senate Committees on Patents, urge the suspension of action on all patent bills now pending and the appointment of a commission made up of unbiased, independent, non-partisan men of national standing to investigate the American patent situation, and to recommend to Congress such action as may appear best.

The Institute, through its various sections and otherwise, has received invitations from time to time to appoint representatives to attend conferences and to otherwise participate in local and national civic affairs embodying engineering features. Under the guidance of the Public Policy Committee the Institute has accepted a number of these invitations and the policy of bringing the influence of the Institute to bear upon civic problems involving the interests of the profession is being encouraged.

The close of the year finds all branches of the Institute's activities in excellent condition, and the continuation of important work is assured. For the first time in the history of the Institute a midwinter convention has been decided upon, to be held at the headquarters of the Institute, on February 26-28, 1913, under the auspices of the Standards Committee. This meeting will be devoted to the general subject of the rating and testing of electrical machinery and apparatus.

THE NATIONAL ELECTRIC LIGHT ASSOCIATION

F. M TAIT
President

LOOKING back over the National Electric Light Association's past year it is evident that the work done and future prospects are greater than ever before. The Association's membership as it enters the year 1913 will be not less than 13 000. The expectation of the Association with reference to the growth and development of company, geographic and state sections has been more than fully realized and several large company sections have been formed and are now in full working order, the Pacific Gas & Electric Company section being the largest addition during the past year. All of the company sections have had a good year and report increasing growth and interest in the various sections' work.

The National Electric Light Association's lecture bureau, embracing no less than twenty-six separate and distinct lectures and papers covering all branches of the central station business, has been of great help to the company and to the other sections during the year. These lectures have attracted considerable attention and it is confidently expected that they will be in greater demand than ever during the coming year.

The Association's monthly Bulletin has been greatly enlarged and its scope of usefulness considerably enhanced by the addition of new and timely matter pertaining to the central station business throughout the world, and particularly in the United States and Canada. This Bulletin is filling a decided place in the regard of all central stations and their employees and its regular monthly arrival is awaited with eagerness. A marked feature of the Bulletin is the excellent question box conducted, and the high quality of the information contained in the replies, usually from the leading men in the industry, makes the Bulletin extremely valuable.

The Public Policy Committee of the Association is fulfilling its mission, and the scope and importance of the work done and in hand for future consideraeion is extremely large. Municipal ownership and its allied difficulties are receiving careful attention and consideration at the hands of this committee. General welfare conditions covering the central station business is being carefully worked out and the experience of the past year's efforts along this line in actual practice in most of the larger companies indicates that the proposition is working out very well.

The various committees to consider all branches of the central station business have been appointed and these committees, embracing the "flower of the industry" in the way of talent, are busily engaged in compiling data, working up reports, etc., to be presented at the next annual convention which will be held in Chicago, Ill., June 2 to 6, 1913.

A number of larger sections, such as the commercial and hydroelectric transmission section, are working along the most advanced lines in their respective fields and by means of numerous committees and sub-committees hope to cover the entire field in a masterly way in their respective branches of the central station business.

The Rate Research Committee of the Association has been, and is now, issuing printed weekly bulletins covering various data relating to the matter of rates, etc., of great interest to the Association's membership.

Altogether, the Association and its work at this time, as it enters the new year, is in most excellent and complete shape to accomplish the greatest possible amount of good for the general membership of the National Electric Light Association in the year to come.

NOTES ON POWER GENERATING AND DISTRIBUTING APPARATUS

E. P. DILLON

DURING the year 1912 there has been a considerable advance in the development of apparatus and equipment for power stations, transmission and distribution systems. An effort has been made to keep up with the increasing demand for electrical apparatus resulting from the wonderful growth and extensions in the use and application of electricity, and the manufacturers are consistently working not only to keep even with such demands but to anticipate requirements, as far as may be possible.

In power house equipment, as well as that in use on other portions of the system, the tendency has been towards units of large capacity, in order to simplify operation, obtain higher economies and reduce first cost. Transmission systems are covering greater territory each year, necessitating increased transmission voltages, and more general distribution of electrical energy from a common generating source. There is a marked tendency to combine numerous systems, resulting in the operation from a central organization of numerous smaller systems of a great diversity of character.

During the year numerous hydro-electric stations have been placed under construction in which units will be installed ranging in capacity from small machines to machines of 17 500 k.v.a.. Many stations having units in excess of 10 000 k.v.a in capacity are now under construction and several in operation. The immediate future promises to bring forth units of even greater capacity for hydro-electric work. These machines are of either horizontal or vertical types, covering a wide range of speeds required for a variety of conditions encountered in various hydro-electric developments. Improvements, due to a wide experience, have been made in mechanical construction, ventilation details and armature construction, which have resulted generally in relatively cheaper, more efficient and more reliable units.

GENERATING STATIONS

H. D. Stephens

In steam practice similar progress is being made. Horizontal units are being built of 15 000 and 20 000 kilowatts capacity for speeds of 1 800 r.p.m. and 1 500 r.p.m., and even larger high speed units are contemplated. Single turbine generators of 30 000 kilowatts capacity for speeds of 1 500 r.p.m. or 1 200 r.p.m. for 25 cycle and 60 cycle service, respectively, are a possibility of the near future. Modifications of design have been effected whereby the materials used are not stressed materially harder than in smaller units.

The remarkable extension of transmission systems in general, resulting in the tying together of systems of a variety of characteristics, has developed a wide field for the application of frequency changers where two systems of different frequencies are operated together. Such apparatus is built in various capacities up to 5 000 kilowatts or larger.

A very interesting application of a comparatively recent development is the use of synchronous condensers floating on transmission systems for the purpose of line regulation. An interesting application of the synchronous condenser for transmission line regulation is on a large power transmission systetm now under construction where synchronous condensers of 15 000 k.v.a. capacity each will be operated at the end of the line and on which the power-factor will be automatically varied from zero leading to zero lagging as conditions may require.

SUBSTATIONS

C. F. Lloyd

The growth of power systems has resulted in a more general application of substation apparatus for electric railway properties, including both urban and interurban service, due to the fact that local power houses are being superseded by large central generating stations which transmit the power over a wide area by alternating current, converting through rotary converter or motor generator substations for railway work. The problem of increased efficiency, simpler operation and proper application to the service required, has been carefully studied and the best experience and judgment followed on this apparatus.

The progress in railway work has made further development of rotary converters necessary in order to meet new operating conditions, as the rotary converter is becoming generally recognized as the proper apparatus for converting alternating to direct current for railway work. In a great many interurban lines the load factor is very low and at certain times the momentary peak loads are extremely high on acount of the necessity of starting and accelerating a number of cars at the same time from a given substation. This momentary condition would ordinarily require rotary converters of much larger capacity than are suited for normal operating service. To meet such conditions railway rotary converters have been developed, having a momentary over-load capacity of 300 percent of normal. The application of commutating poles has made it possible to meet this condition with a very little increase in cost over the regular non-commutating pole converter. Commutating poles have also been incorporated in the design of certain machines having a momentary 200 percent of normal load rating where the design could be made so that commutating poles could be used to advantage.

For certain rotary converters the incorporation of commutating poles, in designs where the output per pole and the speed cannot be increased over that which is now very successfully used for non-commutating pole rotaries, has not been attempted, as the incorporation of commutating poles would result in additional cost and reduction in efficiency, not warranted by the slight extra refinement resulting from their use. In consequence standard rotary converters are commonly equipped with commutating poles only in the 25 cycle size and the larger 60 cycle units.

The use of 1 200 and 1 500 volts for interurban railway work is rapidly advancing in favor, and to meet this condition 25 cycle, 1 500 volt rotary converters of the commutating pole type have been developed. For 60 cycle service two unit outfits consisting of two 600 volt or two 750 volt converters mounted on one bed-plate and operated in series have been adopted.

The principal new development in motor-generator sets consists in their application to 1 200 and 1 500 volt railway service. These high voltage units are built either with two generators in series or with one generator. The motors driving these units are usually of the self-starting synchronous type and, where conditions warrant, are arranged to have a certain condenser capacity for improving power-factor conditions.

TRANSFORMERS

H. H. Rudd

The great distances at which power is being transmitted have brought about the development of apparatus for transmission line equipment for higher voltages each year. There are plants now building and transformers have been constructed for 150 000 volt transmission.

In the tieing together of cities and towns by transmission lines of the various power companies, a network of transmission systems has grown up, passing through many communities which had not heretofore enjoyed the advantage of electric service. One of the most striking developments of the past year has been the use of small capacity installations along transmission lines of various power companies. The outdoor transformer and switching equipment recently developed contributes in a great measure to the development of a small community or a farm load.

The success of the transmission companies naturally depends on their ability to give satisfactory service. There have been a considerable number of installations in which transformers have been utilized for tie-in work; that is, so that one transmission company could supply power to another company, in case of interruption to the service of either one.

The development of the oil-insulated self-cooled transformer for very large sizes has been a factor in the general development work of transmission. Transformers of the self-cooling type are now being made in sizes as large as it is possible to transport by railroad shipment. The elimination of the attendance required, auxiliary piping, and the cost of water has made many an installation feasible which otherwise, on account of the cost of operation, would not have been commercially practicable.

The selection of three-phase transformers or a bank of single-phase transformers depends largely on the choice of purchaser. Opinion is very closely divided on this point. The old question of transformers for connection in star for certain line voltage as against transformers connected in delta is still an unsettled one. The general tendency, however, on the part of American engineers is towards the use of transformers connected in star for the transmission voltage, especially if this voltage is very high.

A very interesting development, or phase in the development of transformers, is the acknowledgment by foreign transmission companies of the superiority of transformers of American manufacture. An investigation of the export business shows that American made transformers are being used for by far the greatest part of all recent high voltage installations in foreign countries.

PROGRESS IN DETAIL AND SUPPLY APPARATUS

G. BREWER GRIFFIN,

Manager, Detail and Supply Department, Westinghouse Electric & Mfg. Company

THE lines of electrical apparatus that come under the heading of detail and supply apparatus, can best be described as those not embraced in power motors, generators, railway equipments and turbines or transformers of over 100 kilowatts capacity. A great deal of this class of material, commonly called "supplies," is used by the central stations in the control and distribution of energy, in addition to the current consuming devices used by manufacturers and residence customers. The growth of this business, so far as the company with which the writer is connected, is concerned, has been remarkable and continuous. Speaking generally, the business today averages in monthly net sales an amount equivalent to approximately four times the net annual sales of 1901. During the period between the two dates there has naturally been marked improvement in the small devices, as well as a considerable increase in the lines produced.

In analyzing the divisions of our business, attention is called to some of the principal lines of product:—

The pressed metal type of fan motor in the eight inch size was perfected by the company in 1908, and in 1912 an entire line of desk and bracket fans of this type were placed on the market, the sales of which were very large. Fans of this type have the advantage of high efficiency in air output, combined with low current consumption and their light weight makes them easily handled. While the past season was extremely poor, so far as weather conditions prevailing throughout the United States was concerned, business in this line was up to the normal.

There has been a rapid growth in the use of heating apparatus. Two new devices have just been added to the line—namely, a "Cozy Glow," two-unit luminous radiator, and a moderate priced, but highly efficient and durable, coffee percolator.

A complete line of insulating material, used and largely made in our own shops, consisting of treated cloths, papers, tapes, soldering compounds and varnishes, impregnating materials, enameled wires, and numerous other similar products, has also been placed on the market.

In the lighting field a new model metallic flame arc lamp has been developed, as well as a new flame carbon arc lamp. The metallic flame lamp is, of course, limited in its application to street lighting almost entirely, although some of them have been used with marked success for indoor lighting on multiple circuits. The flame carbon lamp is rapidly coming into the street lighting field and the tendency for the coming year seems to be an increased demand for this type of street illumination. This type of lamp has been developed for practically all the commercial circuits, both direct and alternating current, and naturally meets with favor where large interiors are to be illuminated at a moderate expense with a well-diffused light. The new lamp is not over 34 inches in length and has a carbon life of about 125 hours. The street series tungsten lighting system is still popular for villages or where the ornamentation of streets is the prime factor in the installation of the lighting system.

The increased popularity of the electric vehicle has naturally brought about a demand for a battery charging equipment which is self-contained and simply operated. This demand has been met in a very satisfactory manner by the Cooper-Hewitt system. In addition, a small mercury rectifier outfit has been developed for the charging of ignition batteries; also a vibrating type of rectifier for the same purpose, both of which are eminently satisfactory, the expense of operation being low and the life of the bulb or the contacts being extremely long. The equipment of gasoline vehicles with electric lighting devices has increased the demand for these small charging equipments, as a great many operators of cars do not run them a sufficient period during the day to keep the battery fully charged from the car generator, and it is desirable from time to time to give the battery a gassing charge from an outside source. These little rectifiers are ideal for this purpose.

With reference to watthour meters; while prices in the market today are extremely low, the same high degree of electrical accuracy and mechanical excellence has been maintained, and it is only the tremendous volume of production that enables any profit whatever to be secured by the manufacturer.

During the past year a complete line of alternating and direct-current seven-inch round pattern switchboard instruments were developed to the great benefit of central stations, in that the scale length is the same as in the nine-inch style, so that the readability is unimpaired and a higher degree of electrical accuracy has been attained in the new design. The floor space occupied by a given switchboard is decreased fully twenty-five percent when compared with one using nine-inch instruments, with a corresponding decrease in the cost of the board, which is thoroughly appreciated by consulting engineers and central station men.

With reference to repairs and supplies, our company has endeavored during the past year to increase its service facilities to its customers, maintaining service departments in several of the principal cities in the United States with a trained corps of men to give prompt service in repairs, erection and inspection of apparatus, sparing neither time nor expense to see that the best possible attention is given customers, believing that our duty does not cease with the sale of the product but extends over the field of application and service.

A special building is now devoted to switchboard work, where the shop men, mechanical and electrical engineers, order clerks, record men and sales representatives are located in adjacent offices, together with a drafting-room covering the requirements of this class of work, so that the most careful oversight is given to this business. From low voltage battery panels to 200 000 volt control equipments, the department is thoroughly equipped, and plans so made that this division of the business has room to grow around its present organization.

Automatic voltage regulators have become almost a necessity with up-to-date central station operators who desire to maintain constant voltage regulation on their lighting circuits. There has been a large amount of business in apparatus of this type during the past year. There will undoubtedly be a considerable increase during the coming year.

Each year the more modern central stations are giving more attention to the proper lightning protective equipment on their lines, looking upon the investment in this respect as a good insurance and comparable with fire protection on plant and buildings. The electrolytic type of lightning arrester, which was introduced by the company some years ago, continues to give the best protection obtainable for high tension apparatus.

A great many other classifications of apparatus which might be termed special, and which are at least variations from standard, have been developed, but the lines are so extensive as not to permit a discussion of them in a brief review of this kind.

PROGRESS IN THE LARGER GENERATORS AND ROTARY CONVERTERS

F. D. NEWBURY

PROGRESS during the past year has been mainly along established lines rather than along new lines. As an illustration, in 1911 gear driven direct-current generators, commutating pole engine-driven generators and commutating pole rotary converters were referred to for the first time. In 1912 the only really new development has been the application of the booster principle to 60 cycle rotary converters, mentioned as a probability in 1911, and the combination of the booster and commutating pole principles to both 25 and 60 cycle rotary converters.

But the progress in established lines of apparatus has been substantial. In the gear driven direct-current generators a number of 3 750 kilowatt, 250 volt, 180 r.p.m. machines have been built. These generators were small enough, in spite of being the largest direct-current machines in continuous current rating ever constructed, to be completely assembled and tested under full-load conditions in the factory. Previously 1 000 kilowatt units had been the largest constructed.

In 60 cycle rotary converters the use of commutating poles, in addition to improvements in design proportions, has raised the limit from 1 000 kilowatts to any rating demanded by the market. A number of 1 500 and 2 000 kilowatt commutating pole 60 cycle units have been built during the past year and contracts have recently been taken for seven 2 500 kilowatt, 60 cycle, 500 volt converters.

The epoch-making New York Edison converters have been put in successful operation during 1912. The largest of these machines has a rating of 3 500 kilowatts, 25 cycles, 270 volts, and can deliver 13 000 amperes continuously and nearly 20 000 amperes for two hours. These machines are not only unique in rating but in the combination of the booster and commutating pole constructions. This combination developed several new and interesting problems which have been successfully solved.

In turbo-generators, speeds and output have climbed steadily upwards. Some of the highest ratings undertaken during 1912 are 5 000 k.v.a., 3 600 r.p.m.; 19 000 k.v.a., 1 875 r.p.m.; and 21 000 k.v.a., 1 500 r.p.m. During the past year, the position of mica as the most satisfactory insulation for the high temperatures and high static strains inevitable in the larger high speed, high voltage machines, has been greatly strengthened.

THE YEAR IN INDUSTRIAL ENGINEERING

J. M. HIPPLE

THE past year has been a notable one because of the activity in the sale and application of electrical apparatus for industrial purposes. The development of apparatus for specific applications has somewhat overshadowed the development of complete lines of apparatus, as is always the case where the manufacturers' facilities are taxed in producing apparatus to fill orders.

There have been an unusually large number of large alternating-current motors installed in steel mills, these motors with their control being in the main of well standardized types. One installation is worthy of note in that it is the first application in America of electric drive to a reversing blooming mill. This equipment, which is being installed by the Steel Company of Canada, consists of two motors capable of delivering maximum peaks of 10 000 horse-power at 70 r.p.m. Power is supplied to the motors through a separate generator and the motors are reversed through the generator field. This application will arouse much interest among steel mill engineers and will doubtless be the forerunner of several similar ones.

Considerable work has recently been done toward electrification in the logging industry. In certain localities in the West, cheap electrical power is available and motors have been used to some extent both in the handling of logs and to drive small portable saws. For the latter work a specially designed motor has been developed, particular attention being paid to low weight and compactness. This motor, rated at one horse-power, 3 600 r.p.m., has a weight of approximately 45 lbs., complete with self-contained reduction gearing.

An application in the milling industry, illustrating the simplicity of the design made possible by the use of electric motors is that of the drive of attrition mills, for grinding grain or similar uses. Two motors mounted on one bedplate, on either side of the mill, revolve in opposite directions driving the two revolving parts of the mill, thus doing away with the necessity for the use of belts or gearing.

The importance of the proper design and selection of control apparatus for motors is being more fully appreciated, and development work in this line has been very active. The indications of previous years have been fulfilled in the demand for a more extensive use of automatic control features. This is true of motors of small as well as large horse-powers. The growing use of very large motors has necessitated the development of larger control units and more elaborate control schemes. In this connection automatically controlled water rheostats have been used extensively. Machine tool applications, especially planer control, are becoming more exacting and, in addition to performing the automatic or semi-automatic operation, it is now necessary for the controller to keep the machine up to an basolute maximum of output as well as to have safety features to protect the driven machine in case of accident. One of the prominent improvements in this line has been the development of the reverser planer motor and control.

The dominating tendency in design is toward simplification, doing away as far as possible with extra connections and making apparatus easily accessible for repair and for renewal of wearing parts.

One of the most interesting developments of the year in motor drive has been the sudden growth in popularity of the electric motor for cranking gasoline engines on automobiles. Early in the year there was some doubt as to how extensively the electric motor would be used in this application. Later in the year, however, sentiment turned strongly in favor of the electric starter and practically all manufacturers who can possibly apply an electric starter to their cars are doing so. The positive driving of the engine at a definite speed for as long as required for starting the engine makes the electric starter ideal in this respect. The additional weight due to this starter is not excessive. A motor having ample power to start an engine of average size has been developed at a weight of approximately 35 pounds, the nominal rating being one-half to one horsepower, depending on the speed. This does not include gears, etc., but indicates the good results which have been secured in this respect by skilled design.

The close of the year is bringing forward a number of new projects, most of which indicate very forcibly the present tendency toward the adoption of any means which will increase the output of a given piece of machinery or factory. The electric drive is responding fully to these increased requirements and it is confidently believed that the coming year will witness many notable economic achievements in industrial lines.

THE SMALL MOTOR FIELD

BERNARD LESTER

NO radical departure has taken place during the year of 1912 in connection with the general principles of design employed in small alternating and direct-current motors. Marked progress has, however, been made in the details of design and the process of manufacture of these motors. These improvements have resulted in the production of motors of a lighter weight, more compact construction and more reliable operation. A comparison of the small motor of today with that which was standard a few years ago would show what remarkable progress has been made by using materials to better advantage. Today it is possible to obtain small direct-current motors and small alternating-current, split-phase induction motors which are of the same general dimensions, rating for rating, and which may be used interchangeably, so far as the principal external dimensions are concerned, in mounting the motor upon the driven machine.

The single-phase induction motor, employing a split-phase winding for starting purposes, continues to be the standard type of small motor employed upon alternating-current circuits. Aside from the reduction in weight and size of the motor, those features which have limited its use in years past, limited starting torque and the use of complicated switch and clutch mechanism, have largely been eliminated. Due to improvements in design, a starting torque is obtained upon this type of small motor when equipped without centrifugal clutch, of sufficient magnitude to take care of the starting condition encountered in the large majority of small motor applications. Improvements in the design of the centrifugal clutch have rendered motors so equipped thoroughly reliable for use where starting conditions are severe.

The engineering problems involved in the application of small motors to labor saving devices are now analyzed on a systematic basis. The old "cut-and-try" method of applying motors has been discarded and the applications are considered very largely in the same way as the application of larger industrial motors to such machines as elevators, pumps, compressors or machine tools. In fact, in applying small motors almost every conceivable operating condition and cycle of operations is encountered. A large amount of technical information gathered upon the application of small motors has become available and the principles involved have been checked up by the results of such applications in the field.

Although there is an increasing diversity of uses to which small motors may be put, the demand has developed more during the last year in the field of devices for the home and for the office. These have centered in a large measure around washing machines, small portable vacuum cleaners, tabulating machines, dictating machines, and a large variety of mailing or duplicating machines which form a part of office equipments. The increased use of motor-driven machines has obviously increased the output very materially and in turn cheapened the cost to the user.

The demand for standard small motors from the electrical dealers and central stations is becoming more stable. In short, small motors are being looked upon by the public as a commercial article, such as the sewing machine or garden hose. The psychological effect of the use of power in small units is one which is seldom borne in mind, probably on account of the fact that it has come upon us so recently. One fact is noticeable, almost universally, in connection with small motor applications, and that is that they are used for labor saving devices, which come in the class of necessities, rather than pleasure-producing devices, which come in the class of luxuries. The fact that the individual in his daily routine is spending less and less of his time in actual routine work and more of his time in actual mind work, or diversion, compensates in a measure at least for the increased demand on the services of the individual. In short, the efforts in the small motor field, although carried out on a commercial basis, have largely resulted in increasing the amount of useful energy expended by individuals in civilized communities. We seldom stop to analyze the amount of physical energy expended by the individual which might as well be furnished by a small motor at very much reduced cost. Experiments show that a man can produce, say, from one-tenth to one-eighth horse-power. The expense of operating a motor of this rating, including cost of current, depreciation, etc., will only total a few cents a day.

THE MINING FIELD

W. A. THOMAS

IN the mining field probably the most important advance as regards the use of electricity has been the remarkable increase in the activity of central stations in supplying power to coal mines. Not only have existing central stations contracted for large amounts of power for this purpose, but large companies have been developed almost exclusively for the serving of power to coal mining operations. Out of this has grown another development in the application of heavy shaft hoisting in coal mines, as heavy electrical hoists have heretofore been used almost exclusively in metal mines, where fuel has been comparatively high in cost. With central station power, however, the situation is very different in that the mining company does not have to purchase the necessary power house equipment for electric hoists, which in an isolated plant makes the use of heavy electric hoisting almost prohibitive on account of the interest and investment feature and the small amount of energy consumed in power as compared with the capacity of isolated plant necessary.

Another important development is a greater use of electrically-driven air compressors in metal mines, of which a large number have been installed with direct-coupled slow speed motors.

In the construction of mine locomotives the cast bar steel frame has become very popular, and operators are even insisting upon this construction in the heavier locomotives, where the advantages are not so important on account of the greater proportion of weight in the frame itself, which ordinarily gives sufficient strength in cast iron. Notwithstanding the large number of these locomotives installed, there has been no report of failure of these frames.

The commutating pole motor has likewise become exceedingly popular, as this feature is particularly beneficial in this service, where the electrical equipment suffers extremely heavy overloads at times and where the care and inspection given to the equipment are a minimum.

MOTOR-DRIVEN CENTRIFUGAL PUMPS

W. F. PATTON, Jr.

ONE of the most noticeable recent developments in the design of centrifugal pumping machinery has been the trend toward higher speed. Many of the electrical manufacturers are carrying on experiments and each trying to outdo the other in satisfying the pump builders' demands. Quite naturally the pump builders will desire higher speeds because it means reducing the number of stages on their centrifugal pumps and in this way reducing the first cost. By the use of higher speeds, higher efficiency can also be obtained. It is not difficult to obtain high speeds with alternating-current motors and steam turbines, but on account of commutation this becomes a more difficult problem with direct-current motors.

Several municipal pumping plants throughout the country have installed self-starting synchronous motors for pumping service. The chief advantage of using this type of motor is the power-factor corrective effect and the pumping load is ideal for this feature inasmuch as the load is usually steady and constant. A careful study of the torque requirements at starting is most desirable to insure the best application of this type of motor for pump drive.

The self-starting direct-current motor is still increasing in popularity throughout the mining regions, this motor being especially designed so that it can be connected across the line without the use of a starter. These motors can be applied to any centrifugal type of machine, but are most generally used for mine pumping. They can be placed at remote distances from the power plant and can be started by simply closing the circuit breaker. While this type of motor is most popular with mining companies, it can be applied to almost any service where the conditions are thoroughly known, and it is a noteworthy fact that one coal company alone has purchased over two hundred motors of this type, showing conclusively that these motors are giving satisfactory service.

Owing to the low-head, the centrifugal pump has many advantages for dry dock pumping, and it is probable that electrically operated dry docks will become still more popular. One of the most recent installations in New York state included twelve 100 horse-power motors to be used with a pontoon dock. An electrically equipped dry dock is very flexible in operation and, inasmuch as the operator has complete control of each unit, great saving in expense over the steam-driven dock is possible, particularly when only a part of the dock equipment is in use at one time.

In the irrigating field the centrifugal pump is deservedly popular. The farmers in the irrigating districts are unquestionably in favor of electric motor drive where power can be purchased, and in those districts where power lines have been extended the electric motor is usually the one type of drive that the farmer will consider. The squirrel-cage motor continues to be the most popular type for this class of service. As it has satisfactory starting characteristics and as constant speed is usually required, its simplicity and reliability offer strong arguments in its favor. Progressive central power stations have shown very much interest in this class of service and are investigating thoroughly their undeveloped fields so as to extend the power lines for loads of this nature. With proper water storage facilities pumping can be done at times to suit the power stations and in this way increase their load at off peak periods.

ENGINEERING DEVELOPMENTS IN DETAIL APPARATUS

T. S. PERKINS

IN looking back upon the year 1912 with a view of defining the marked tendencies and the progress made, we are confronted by the difficulty that an attempt to full enumerate the developments would require a statement as to practically every important piece of detail apparatus made. Stimulated by the requirements of a broadened market and greatly increased demand, new developments and improvements in design have been very rapid. The fundamental tendency has been to maintain and improve quality despite strong demands for lower costs.

The Lighting Field—The flame carbon arc lamp has been made a commercial success with the result that larger lighting units are now available; the cost of illumination has been reduced, and the performance has been made more reliable. With the continued business prosperity, the municipalities and smaller towns have been able to avail themselves of the later developments in the lighting field, with the result that there has been a country-wide movement toward the installation of better lighting equipment. Merchants' organizations and independent organizations have in many cases hastened the advent of the latest lighting devices. A marked result of this is the multiplication of the so-called "White Ways," which have generally proven a good investment, financially as well as in other ways, for the community where they have been installed. The long life, high candle-power flame carbon arc lamp, while one of the most important means of securing increased illumination, has by no means monopolized the field in the development of illuminating engineering. The metallic flame lamps have played an important part, and in the smaller towns and in the outskirts of the larger cities the series tungsten incandescent lamp has had its share in the increased illumination. In the field of tungsten lighting the reflectors and associated apparatus have been improved and cheapened. This, together with the high efficiency of the tungsten incandescent light, makes this means of illumination one of the most satisfactory for the smaller towns and suburban districts.

Heating Apparatus—The field for electric cooking and heating apparatus continues to extend and broaden, as there is a continual increase in their application for both industrial and household uses. As electric cooking has become more common, a demand has arisen for cheaper grades of utensils possessing a plain but serviceable finish, rather than the elaborate designs which were first produced. This wider demand also calls for apparatus which is somewhat more fool-proof in construction, as the average electric cooking utensil requires, even at the present time, more careful operation than is the case with the corresponding gas heated article.

The industrial applications of electric heating continue to extend. Electrically heated bake ovens, and linotype and monotype printing pots are among the latest applications, and it would seem to be only a question of overcoming the conservatism of the operators of a large variety of industrial apparatus before the use of electricity for special heating purposes becomes widely adopted.

Rectifiers—There has been a great expansion in the use of electric vehicles, and this has caused a proportionately large demand for battery charging rectifiers. The marked tendency to use larger batteries than in former years, especially in large trucks and other commercial vehicles which are now becoming common, has resulted in a demand for the larger sizes of rectifiers and has brought the 50 ampere capacity into increased importance. The designs now in use have proved so satisfactory that the efforts during the past year have been directed mostly toward refinement of details and reduction of costs rather than to the production of new designs. The one radically new feature of the year has been the appearance of the vibrating type of rectifier. So far, this is available only in small sizes suitable for charging the ignition batteries used on gasoline automobiles, but the wide introduction of electric lighting on motor cars recently has created a very large field for small rectifiers for which the vibrating type is especially suited.

Lightning Protective Apparatus—The past year has been a very active one in lighting protective apparatus of all kinds. For the lower voltage and lower powered lines, the older shunted spark-gap types continue popular and successful; while for the higher voltages and large powered installations the electrolytic arrester is used almost exclusively. This latter type is now a perfected device of great effectiveness and reliability, especially since most operators have become familiar with it and have been converted to the practice of daily charging. The developments of the past year have been mostly in the line of refinements in design, leading to reductions in size, weight and cost, and at the same time improvement in quality. There has, however, been a large demand for electrolytic arresters for very high voltages, and arresters for 110 000 volts are now not uncommon, while arresters are under construction for 165 000 volts, the highest voltage yet employed commercially.

Fan Motors—The past season was marked by the advent of the drawn steel construction for fan motors, greatly reducing the weight and improving the appearance. A tendency was noted towards designs of lower speed fans for residence use, with their resultant quieter operation.

Ozonizers—The portable ozonizer, one of the new lines of apparatus, is increasing in popularity, which should materially add to the growing uses of electricity in offices, dwellings and public places. So many useful applications of ozone have been discovered that the coming year will see greater development along this line.

Resistors—Greater efficiency and increased refinement of operating conditions, safeguards for the operator, greater regard for appearance, and redesign for decreased costs characterize the development of rheostats. Finer regulation is being demanded by central stations, together with better appearance, and all field rheostats are now being made with an increased number of steps and more particular regard for the exact operating conditions.

Measuring Instruments—The low-priced watt-hour meters placed upon the market the year previous were of limited application, as they were made for low capacity and 60 cycle service only. The year 1912 has seen these lines extended to cover all commercial frequencies and capacities.

An interesting new line of portable meters has been developed, based upon the moving coil principle, distinguished by very light movements and completely shielded against external fields. A line of low-priced, small size portable and switchboard graphic meters has been perfected. These operate upon the solenoid and iron-core principle and have a continuous straight paper chart, instead of the circular charts used with the previous cheaper graphic meters. The die casting process has been applied to pole-piece construction of permanent magnet indicating instruments, making possible the design of highest grade meters at a very low cost, mounted in very small cases for use in connection with automobile starting, ignition and lighting outfit work. There has been further development in the seven-inch type of switchboard indicating instruments first introduced the year before. The present demand for these meters exceeds that of any other size. They have been adopted as standard for many new switchboard designs, as they occupy practically half the space of the previous nine-inch, round-type meters and result in more compact switchboards. Vertical edgewise meters, due to their curved scales which are read with difficulty, are less in favor, except for extensions to previous installations. Meters with black dials and white figures and pointers are being used extensively, particularly where good readability under conditions of artificial illumination is desirable.

THE IRON AND STEEL INDUSTRY

BRENT WILEY

DURING the past year there has been practically a universal endorsement of the commutating pole, direct-current motor, including various classes of industries but more especially the iron and steel industries. Many improvements in the mechanical features, such as frames, bearings and shafts, insulation, types of winding, etc., have been devised, but the commutating pole is one of the most important improvements. At the present time this feature is incorporated in motors for machine tool drives and similar applications, and for the more severe classes of intermittent service, such as street railway and steel mill applications where the work is of a widely varying and often of a reversing nature. In machine shop work the commutating pole motor is capable of wide ranges of speed variations with heavy overloads, and the intermittent rated motor gives greatly improved commutation through a wide range of load conditions which, as a rule, include high accelerating peak loads and even higher loads during reversing for crane and general mill service.

The use of commutating poles results in greater continuity of service, less supervision of apparatus and, in many cases, increased working capacity of machinery. The net result is increased plant efficiency and, in addition, there is much to be gained by the incidental advantages which become more definitely established as the user's experience with this design of motor is increased.

A number of new steel mills have been started during the last several months and, in almost every case, electric drive has been considered for the main rolls. In many cases it has been adopted in preference to steam engine drive. The larger steel companies have existing electric power plants which deliver power at a cheaper rate than steam power can be generated for an isolated mill engine, the advantages being obtained by the use of gas engine or turbine drive. In the latter case the plants may include low-pressure steam turbines, using exhaust steam from existing mill or power engines, or may include turbines using steam from the blast furnace plant, where steam can be generated very economically by burning blast furnace gas under the boilers.

The water power companies and central station companies are fast realizing the mutual advantages which contracts with the various steel plants afford. During the past five years there have been approximately 140 000 horse-power in main roll motors installed in the United States, including about 75 units. The results obtained by the motor operated plants have been carefully analyzed and the operating conditions and requirements definitely established. This is a decided point of advantage offered by motor drive as compared with steam engine drive, for accurate records over long periods of operation can easily be obtained.

With the conditions outlined, the power companies have a definite basis on which to establish their proposals, and they are finding that in a majority of cases they can well afford to make a rate for power which is advantageous to the steel plants. Included in these advantages are the following points:—

The rate is advantageous to the customer.

The first cost of steel plants with motor drive is cheaper.

The depreciation charge on power apparatus is greatly reduced.

The up-keep charge on the mills is less.

The operator is relieved of the supervision of an adjunct to his business.

The reliability of the service is greater than with the isolated power plant.

The reliability and many incidental advantages of motor drive for steel mills are well established, and it has received the indorsement of many prominent steel mill engineers. The first and practically only question regarding the majority of the applications is "cheap electric power" and, as the central stations are doing much to solve this question, it is safe to predict that motor drive will become more universally adopted in steel mills, even for the more severe classes of service, such as reversing mills, etc.

Hydraulic power as used in steel plants has many disadvantages, especially in cold weather, when the difficulty of preventing freezing requires great precaution and extra expense. Motor drive is superceding hydraulic drive in many of the applications. A practice which is becoming quite general, is the use of motors for lifting the doors of the open hearth furnaces. The mechanical features are simple and a practical design is to make a separate and complete unit, including motor, control, gearing, etc., for each door.

Several coal dock equipments have been installed during the past year and though steam operated rigs were estimated on originally, the majority of the plants will be motor operated throughout. Power will be furnished by central station companies. As compared with steam drive, the first cost of the dock equipment is less, and the operating costs are much less.

THE ELECTRIC VEHICLE

BERNARD LESTER

AT the beginning of 1912 those familiar with electric vehicle progress looked for the greatest advances in the field of commercial electric trucks. On the contrary, although the use of electric trucks has advanced in an almost remarkable degree, the progress of electric pleasure vehicles has attracted greater attention on the part of the public. As to types of construction, the coupè body continues to be by far the most popular for the electric pleasure vehicle. The electric coupè of a few years ago has been transformed from a lofty box-like conveyance with short wheel base, into a low, roomy, smooth running car. The entire appearance has been changed and the electric coupè of today is one of the most attractive and comfortable conveyances to be found.

Certain distinct features are responsible for the increased success of the electric pleasure vehicle:—

1—Improved operating characteristics of the car as a reliable transportation agent. This has been brought about largely by improvements in the motor, controller, battery and method of transmitting the power to the drive axle. The improvements in details of motor construction have been characterized by increased efficiency, quieter operation, more rugged construction, combined with lighter weight. Chain drive has largely been replaced by some form of gear drive, with which the motor is either mounted rigidly on the rear axle or suspended from the chassis and connected to the rear axle by a jointed shaft.

2—A marked improvement in the construction of the chassis and body of the car. This has led to a greatly improved appearance, convenience in getting into and out of the car, and added comfort while riding. The modern electric is invariably beautifully upholstered and highly finished.

3—Improved facilities for taking care of the electric car. The number of garages which are in a position to supply the needs of the electric is constantly being increased. The central station interests, too, are establishing charging points, not only in the downtown districts but also in the suburban districts. Charging equipments suitable for the individual private garage, which are both inexpensively maintained and simply operated, have greatly eliminated objections which have been made against the use of the electric. These factors, combined with the fact that due to improved construction, the electric of today has a much larger field of operation than formerly, have greatly reduced the trouble and expense of maintenance.

The objections which have often been raised against the electric car, i. e., limited capacity, as to speed and range of travel, are to a large measure being eliminated. The electric is not a complete competitor of the gasoline car, nor is the gasoline car a complete competitor of the electric. The electric is not, and perhaps never will be, a touring car, but as a serviceable city and suburban car it has many points of advantage. Fortunately, the manufacturers of these cars are realizing that record tours with the electric mean little, and place this type of car in an entirely wrong light before the public. The speed craze has naturally brought about legislation against high speed in residence and city districts. The electric vehicle will invariably be found capable of equaling or exceeding the legitimate speed limit, and in crowded and congested districts the thoroughly simple manner in which the electric is controlled gives it a distinct advantage.

Activity in the field of commercial electric vehicles continues to grow at a remarkable rate. One factor that is particularly noticeable is that the large companies, such as wholesalers, department stores, express companies, etc., who have tried out electric trucks in individual cases are employing them now in large fleets. The difficulties in obtaining reliable operators and intelligent supervision are being overcome by the rapid accumulation of a large amount of data pertaining to the operation of electric vehicles, which is being disseminated by manufacturers and central station interests.

The electric vehicle business as a whole is being greatly helped by the increased coöperation between the three large interests which derive profit from this field, i. e., the manufacturers of the electric vehicle, the manufacturers of its component parts, and the central stations interests who supply the power. The Electric Vehicle Association of America and several of the largest central power stations have also done a great deal along broad publicity lines to promote the use of electric vehicles.

PROGRESS IN RAILWAY CONTROL APPARATUS

G. M. EATON

DURING the year 1912 there has been a notable increase in the use of indirect control on small cars, even where multiple-unit operation was not contemplated. The excellent results obtained from control of this type during 1910 and 1911, led to this wider application in 1912. The closing of a year's operation for fifty equipments of this control on one of the largest city systems showed remarkable results with respect to reliability and low cost of maintenance. The year is noticeable also for the first application of field control to cars, to any considerable extent. This control was tried out on the Pennsylvania locomotives and on a few sample car equipments, but it was not until 1912 that considerable numbers of equipments, including this feature, were put in service. The widespread adoption of commutating pole motors has also been noteworthy. As a part of this extended use of the field control principle, a drum type controller for operating commutating-pole motors in this way has been developed.

The first large installation of automatic unit-switch control using trolley power, was completed during the year and put in service in the Cambridge Subway.

In the field of single-phase equipments, the year has seen the beginning of operation of the New York, Westchester & Boston system, the largest single-phase motor car installation which has ever been undertaken. This road employs a simplified type of control, using only seven switches for handling double equipments of 170 horse-power motors with automatic acceleration, which affords the simplest system of controlling motors of this output which has ever been produced.

For use on 1 200 and 1 500 volt equipments, with occasional operation on 600 volts, a combined unit for supplying high pressure compressed air for the brakes, low pressure air for forced ventilation, and a 600 volt circuit for lighting and control circuits, on the dynamotor principle, has been developed, to save both space and initial cost. The 1 200-1 500 volt equipments have been strengthened in a number of features. One of the distinct developments for both direct and alternating-currents has been a locomotive layout, with all the control apparatus in an easily accessible location in the center of the cab, protected by a grounded screen, and the location of blowers, compressors, etc., in end hoods, outside the cab.

In the matter of high voltage direct-current operation, a system of indirect control has been developed for use on single cars using trolley current for operating the control circuits, and thus rendering the use of a dynamotor unnecessary. This makes possible the employment of indirect control for single car operation on high voltages, with all of the advantages in the way of removing the heavy current carrying circuits from the car platform, which this control carries with it, without the necessity of employing a dynamotor.

In general also, the year has seen a reduction in the weight and size of control equipments for all sizes of motors for high voltage operation.

During the year developments of control of dimensions suitable for use on low frame cars have been undertaken, and a general lightening of the mechanical structures of control apparatus has also been brought about.

One interesting development in the field of mining locomotives is an electrically driven gathering reel, for gathering locomotives. This reel is in effect an electrical spring, in that it maintains a fairly constant torque at all times, whether the reel is being unwound, or is winding up the cable. Sufficient resistance is kept in series with the motor so that it may remain connected across the line indefinitely without injury while at a standstill.

SEARCHING FOR THE UNKNOWN

C. E. SKINNER

It may be that "there is nothing new under the sun," but when we come into contact with the unending requirements for materials, processes and principles in our modern civilization we are forced to the conclusion that our knowledge of old things is indeed limited. Compared to a like period a century ago we have made marvelous progress in the last year. Compared to our requirements and desires we have all but stood still. We have made marvelous progress in medicine and surgery, but cancer is still on the list of incurables. The science of aviation has grown up as in a night, but the list of fatalities is still very great. We have ocean vessels which must surpass the wildest imaginations of our forefathers, but the "Titanic" was lost. Heavy electric traction has become a reality, but trunk lines are not yet generally electrified. We transmit electric currents at a pressure of 150 000 volts, but we cannot be sure that we can operate through all storms. We have many metals in daily use that a few years ago were considered curiosities, but there are still many that are not yet commercialized and we fail to control as we wish many of the properties and combinations of those which are commercialized. We have had iron and steel since the dawn of history, and yet study and research into iron and seeel was never more active than at present. If we have accomplished much, it is only to find that for every success there are many failures, and for every epoch-making invention or discovery there are ten thousand details that must be patiently and carefully worked out to make such inventions of general use.

If we have failed to cure cancer, if we lost the "Titanic," if travel by aeroplane is not safe, all these things are but additional stimuli to still greater and better effort. Our failures often indicate the way to success, and each success gives us new tools with which to attack the unsolved problems. No startling and epoch-making invention, such as X-rays or wireless telegraphy, has been announced during the past year, yet there has probably never been a year of greater achievement in all lines of research than during the last twelve months. This statement is based on the fact that we have better tools, better methods, and there are more workers than ever before, and the present almost universal prosperity has given new problems to solve and new rewards for their solution. With all the accumulated methods and tools and principles should we not expect still greater and more startling inventions and discoveries than those with which we are now familiar?

TRANSFORMER PROGRESS

W. M. McCONAHEY

A SURVEY of the field of transformer development for 1912 shows a general trend towards the adoption of voltages of 100 000 volts or higher for power transmission purposes. In fact, "trend" is scarcely a strong enough term because most of the new plants that have been planned or constructed have been designed to transmit power at voltages exceeding 100 000 volts. It is natural to expect this as undeveloped waterfalls become more and more remote from the points of power consumption. The general factors that contribute to the use of these falls for generating power to be transmitted over distances not hitherto considered economical, are the increased cost of fuel and the advances and improvements that have been made in electrical power transmission apparatus. Among these, transformers occupy a very important place. Special investigations dealing with the problems of high voltage have been carried out and the knowledge gained therefrom has been made use of in the design of 150 000 volt transformers that should be just as reliable as were the first 110 000 volt transformers that have stood the test of service so well. In fact, the step to 110 000 volts at the time it was made was almost as great a step so far as the transformer is concerned as the step to 15 000 volts.

It is becoming generally recognized now that where large amounts of power are concentrated in one generating station it is necessary to design the transformers as well as the generators so that they will not be injured by mechanical stresses due to external short-circuits. In some cases protection against trouble of this kind has been secured by the use of air core reactances. In the case of large 25 cycle apparatus the air core reactances may be necessary but for 50 or 60 cycles, experience seems to show that with carefully designed generators and transformers they are not necessary.

The great saving that can be made in the cost of large high voltage sub-stations by the use of outdoor instead of indoor apparatus is being appreciated more and more. Outdoor apparatus has now been developed to that point where it is becoming standardized. Stations are simple and of low cost, and can be extended easily at any time. The special suitability of large self-cooling transformers for such stations is being more generally understood and a large number of them have been installed during the past year.

There are many transmission lines of from 22 000 to 44 000 volts passing by towns where small amounts of power can be used for lighting or for manufacturing purposes. In such cases the income generally will not warrant the building of an indoor sub-station. It is here that the small outdoor sub-station becomes available as a means of enabling the power company to secure this class of business at a profit. The outdoor sub-station can be constructed at small cost by erecting a few extra poles and a platform. During the past year much has been done in the development of apparatus for this class of service and its use has been widely extended.

The use of dis tributing transformers has been largely extended for 6 600 volt and 11 000 volt service. These, as well as the standard 2 200 volt transformers, have not undergone any radical change in the design but have been improved in details wherever improvements were found possible.

THE GASOLINE-ELECTRIC AUTOMOTRICE

FRANCIS E. DRAKE

NEARLY every distinct forward movement in industrial progress comes after a cycle of efforts and failures to make of practical use new and progressive ideas. These cycles usually represent the premature introduction of devices, their extremely slow economic development or utter failure and abandonment, then a later resurrection and adoption. The self-propelled passenger carrying car for railways is a striking example of a much needed unit, which for many years eluded the best efforts of railway authorities and engineers, but which at last emerges in a thoroughly evolved and practical condition.

The gasoline-electric car, or "automotrice," as it is termed in Europe where the first important developments took place, began to receive serious attention in the early nineties. The advent and phenomenal success of the trolley car seemed to urge pioneers in the development of the gasoline-electric car to a prompt introduction on steam roads of their much heralded independent unit, designed to give steam road passengers the comfort and modern convenience of electric traction. But in spite of unlimited financial and railway support, and the sympathy and encouragement of an expectant public, this forerunner of a later necessary and successful type passed into oblivion. Various other solutions were sought and tried out;—high pressure steam cars, coal, coke and oil fired; gasoline engines with direct mechanical transmission; storage battery cars—all have been designed and offered for trials in different forms. Such trials have proven conclusively that electricity must play its part in the independent railway unit, since no other means has been found which assures a proper and sufficient torque in starting and accelerating, together with a progressive and convenient speed control. Thus about two decades have elapsed between the first introduction and the definite successful approval and adoption of the gasoline-electric car.

The pioneer types of gasoline-electric cars all depended upon storage batteries as auxiliaries to insure the continuous movement of the car even though the engine should fail, and also as a load for the engine which at that epoch was crude and could only be operated at or near normal speed. It is undoubtedly due to the undeveloped condition of the internal combustion engine that the early gasoline-electric car failed to find a regular place in the traction development of the times. Automobile engine development and progress placed the internal combustion engine in a preferred position for its employment in solving economically the automotrice problem.

To engineers engaged in electric traction along existing lines where large units, heavy trains and high speeds are the usual conditions, the gasoline-electric automotrice may seem an unwelcome, if not an impossible aspirant for a position in the railway, or more broadly speaking, traction field. In the electrical engineer's opinion, its limited power and apparently restricted capacity limit it to a comparatively insignificant field. An awakening sense in traction engineering and operation is, however, rapidly developing along the lines of efficiency and more attention is being paid to the choice of proper elements or machines to perform given work. The same sentiment and judgment which governs the elimination of heavy grades, causes electrification of terminals and difficult sections should equally control the lesser traction elements and those to which the automotrice more strictly is applicable.

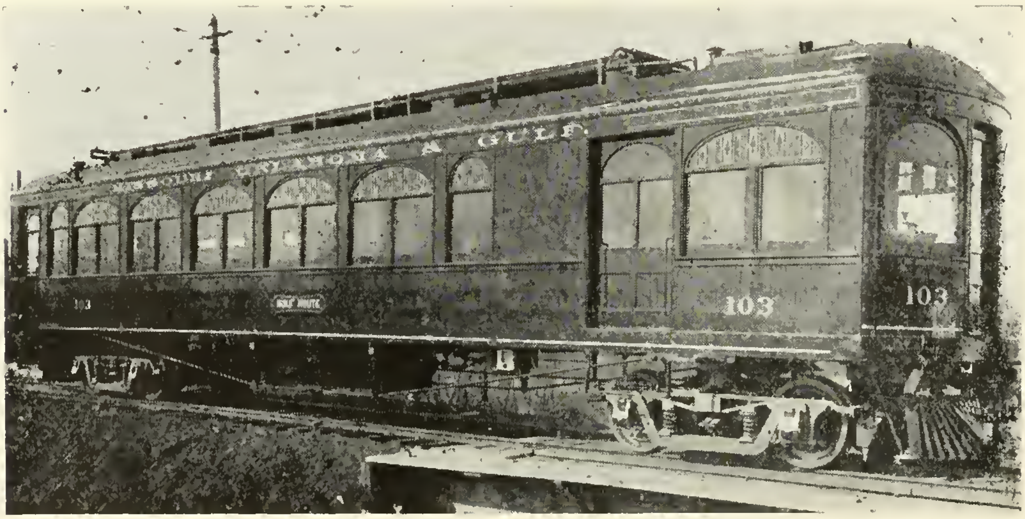

FIG. I—GASOLINE-ELECTRIC AUTOMOTRICE "DRACAR"
On the Missouri, Oklahoma & Gulf Railway.

Any large railway system, when spread out in plan, represents a network with feeders or branches diverging or radiating from main or chief arteries of travel. It is indeed a fortunate railway system whose passenger receipts from feeder and branch lines show a profit over cost of operation. Yet the public must be served even though a deficit results from such service.

The average branch line service on the steam roads does not fill a steam train, nor can it justify the expense of running one. Usually these trains are composed of engines and equipment considered obsolete for the main line service. The locomotives are notoriously wasteful and often in very bad condition. This branch line traffic thus ordinarily represents the most expensive per mile service on the entire road, while the receipts are often less than operating costs. For such cases the gasoline-electric automotrice is a wonderful relief . The actual operating costs are much less than with locomotives, without considering the collateral expense attached to steam service, such as round-house and terminal service, water tanks, coaling chutes with attendants, etc.

The first successful or important installation of the gasoline-electric automotrice was begun on the Arad-Csanad Railway in Southeastern Hungary. A service begun in 1905 has grown from seventeen pairs of trains daily under steam operation to seventy-two pairs with automotrice operation. The fares were reduced about one-third, but the receipts have constantly grown. Where a severe deficit existed under the old way, the new service brings a net surplus of between forty and fifty thousand dollars per annum.

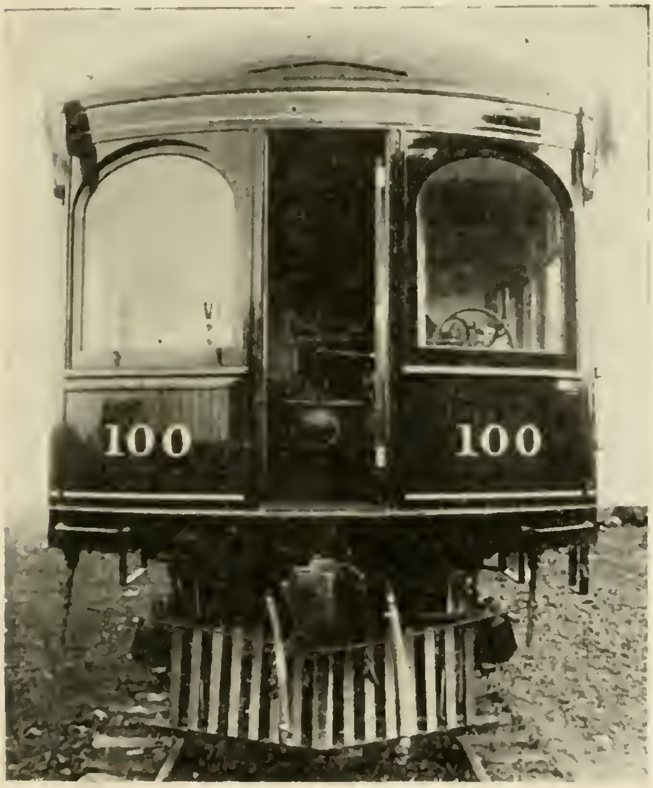

FIG. 2—FRONT END OF CAR, SHOWING POWER GROUP

Other European successes have likewise been recorded in Germany, Holland, Sweden, France and England. A very great variety of service has been experienced, from the summer excursion type to main express trains. The European experience and practice has recently become available on this side of the Atlantic and several cars have been built chiefly for Western railway conditions.

Briefly described, the car may be compared with a modern interurban trolley car, but with trolley removed and a power plant installed in the forward end of the car. The car body, trucks and traction motors are essentially such as are regularly adopted in interurban work. The power plant consists of a multi-cylinder gasoline engine direct-coupled to a 500 volt electric generator. These two units are mounted on one constant sub-base which in turn is bolted to the car floor or frame. From this group the energy generated is conducted to a control system comprising series-parallel connection of traction motors with field regulation of generator and a varying carburettor throttle. The gasoline supply is carried in two tanks cross-connected and arranged so that either may deliver fuel to carburettor by gravity. The cylinder jackets are supplied with cooling water which is circulated by a positive geared pump, driven by the cam shaft. The cooling effect is obtained by passing the hot water through a copper tube radiator placed on the roof of the car. In winter a portion of the jacket water is circulated in the radiating pipes of the car heating system.

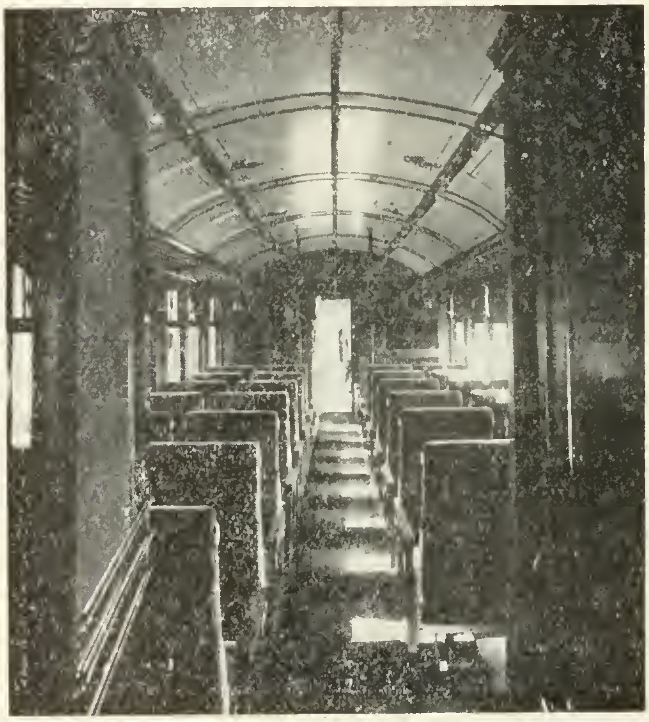

FIG. 3—INTERIOR VIEW OF 56 FT. "DRACAR" ON M. O. & G. RY

Straight and automatic air brakes are installed in a manner usual to interurban electric cars. A full complement of whistles, foot gongs and conductors' signals are provided.

The series-parallel control is essentially the same as used in tramway practice. The contacts for ten steps of field resistance are incorporated with the series and parallel sections of the controller. The control lever is also arranged to open or close the gas admission mechanically, thus permitting a wide range in the accelerating and running speeds.

The motors are usually mounted on the forward truck and are chosen from standard types according to duty required. One of the features of the gasoline-electric automotrice which appeals strongly to the practical railway manager is that the traction motors are standard, the controllers are of usual type, with but slight alterations, and the generator of such type as to insure long life and minimum repairs. The only portion of the equipment for which comparative maintenance figures are not available is the engine. This unit in turn has now been so revised and refined in the several years severe, though successful European operation, that the matter of maintenance may be safely estimated.

The engine is designed nominally for 950 to 1 000 r.p.m. Equipments of 90 and 140 horse-power rating are supplied with standard cars seating from 44 to 72 passengers, depending upon the floor plan and seating arrangement adopted. The smaller of these equipments is intended for use where the schedule speed is approximately 25 miles per hour and the maximum on level tangents is 35 miles per hour. The larger equipment is for use where the schedule is based on approximately 30 miles per hour and a maximum speed of 40 miles per hour with capacity for hauling a trailer suitably designed for 40 to 60 passengers. A daily mileage of 150 to 175 miles may readily be taken as an average under ordinary conditions. Local conditions, however, always control total mileage.

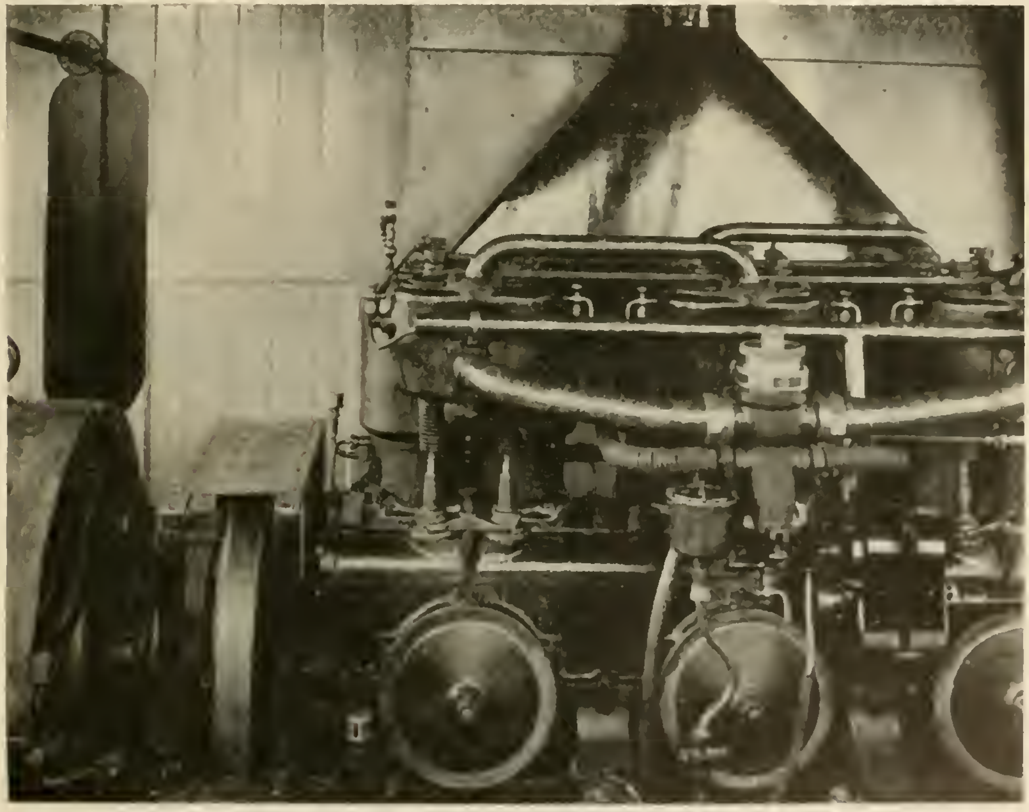

FIG. 4—PORTION OF POWER GROUP OF 90 HORSE-POWER AUTOMOTRICE

The car and equipment here illustrated is the "Dracar," adopted by the Missouri, Oklahoma & Gulf Railway. This car has the admirable feature possessed alone by this particular type of automotrice, i. e., possibility of operating from either end in either direction. Duplicate controllers and instruments are placed in the vestibule and farthest from the engine. When it is desired to reverse the direction of the car, the motorman leaves the gasoline engine running under reduced speed, takes his controller handles to the other end, as in trolley practice, and takes up the control at the distant end.

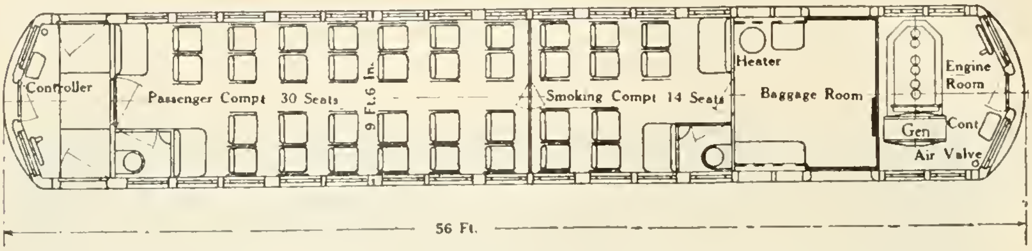

FIG. 5—FLOOR PLAN LAYOUT OF GASOLINE-ELECTRIC AUTOMOTRICE

The engine and complete group have been so carefully worked out and balanced that distant control is entirely satisfactory. In stations where only limited stops are made, the engine is throttled down and not stopped. The engine is started by "cranking" just as an automobile motor, the compression being reduced momentarily during starting. Magneto ignition is employed. The magneto is mounted upon an extension of the shaft serving the automatic stop-governor.

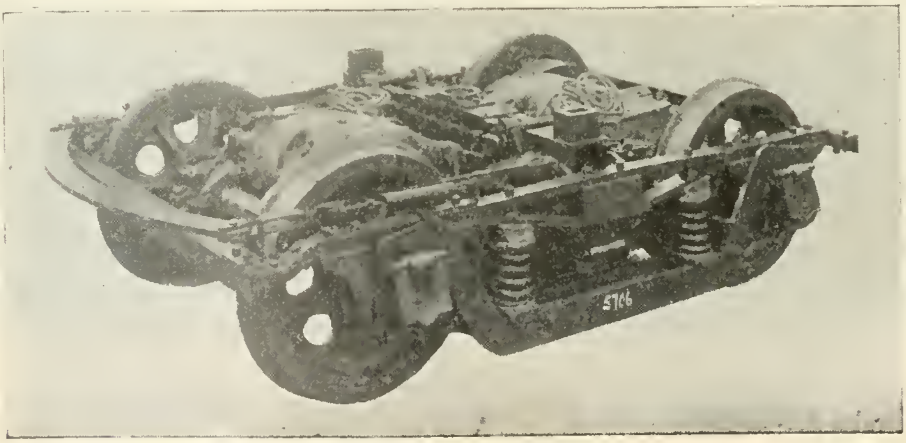

FIG. 6—FRONT OR DRIVING TRUCK EQUIPPED WITH TWO RAILWAY MOTORS

The M., O. & G. Ry. Dracar is 56 feet long over bumpers and 9 feet 6 inches wide over all. It is divided into four compartments: engine room, baggage, "jim-crow" and first-class compartments.

Very attractive individual reversible plush seats have been provided. The latest form of arch roof and plain but well finished interior conduces to attractiveness. It is obvious that any form of car or suitable interior can be adopted for use with this combination. It is equally obvious that different classes of service may be performed. The growing need of office cars, as the railway officials' former private cars are now designated, makes the automotrice extremely attractive. Instead of the office car being attached to a passenger train with only certain schedule stops, or being expensively hauled "special" by a locomotive, the automotrice office car is operated by a limited crew with the fullest possibility of stopping at will for inspection or conference. It would be, in fact, absolutely independent. Its cost of operation is at a minimum for such service. Such a car in the service of the technical department of railways can be equipped with various recording instruments for track inspection, even indicating variations in rail height and other irregularities and imperfections that are most difficult to secure with existing means.

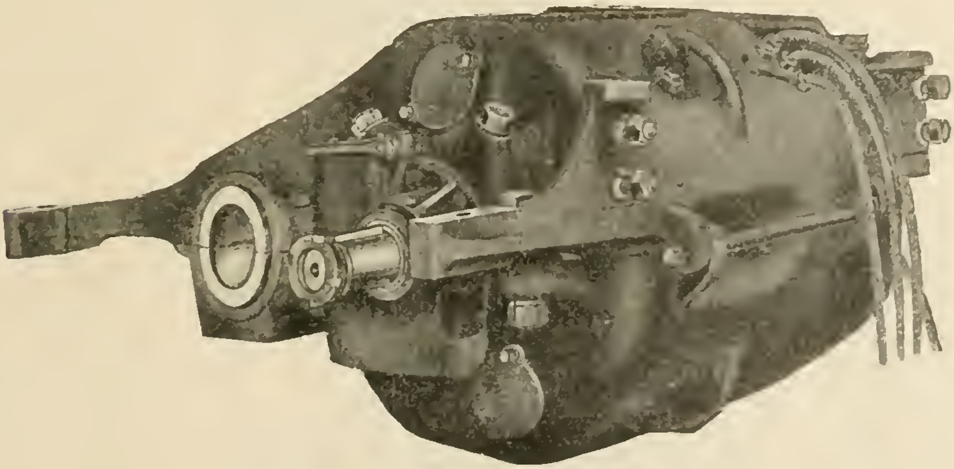

FIG. 7—STANDARD RAILWAY MOTOR USED ON GASOLINE-ELECTRIC AUTOMOTRICE

In the field of electric traction the automotrice may successfully perform the service of owl cars. In case of projected extensions it may be utilized to develop or demonstrate the traffic, that later electrification may follow. By certain trackage arrangements the automotrice could usefully serve as a unit, operating partially on steam railway tracks and then enter and penetrate to civic centers for the accommodation of an entirely new traffic thus created.

Within the limits of 40 tons total weight and a maximum speed of forty-five miles per hour, the automotrice will be a most potent factor in making possible greater conveniences for the public and

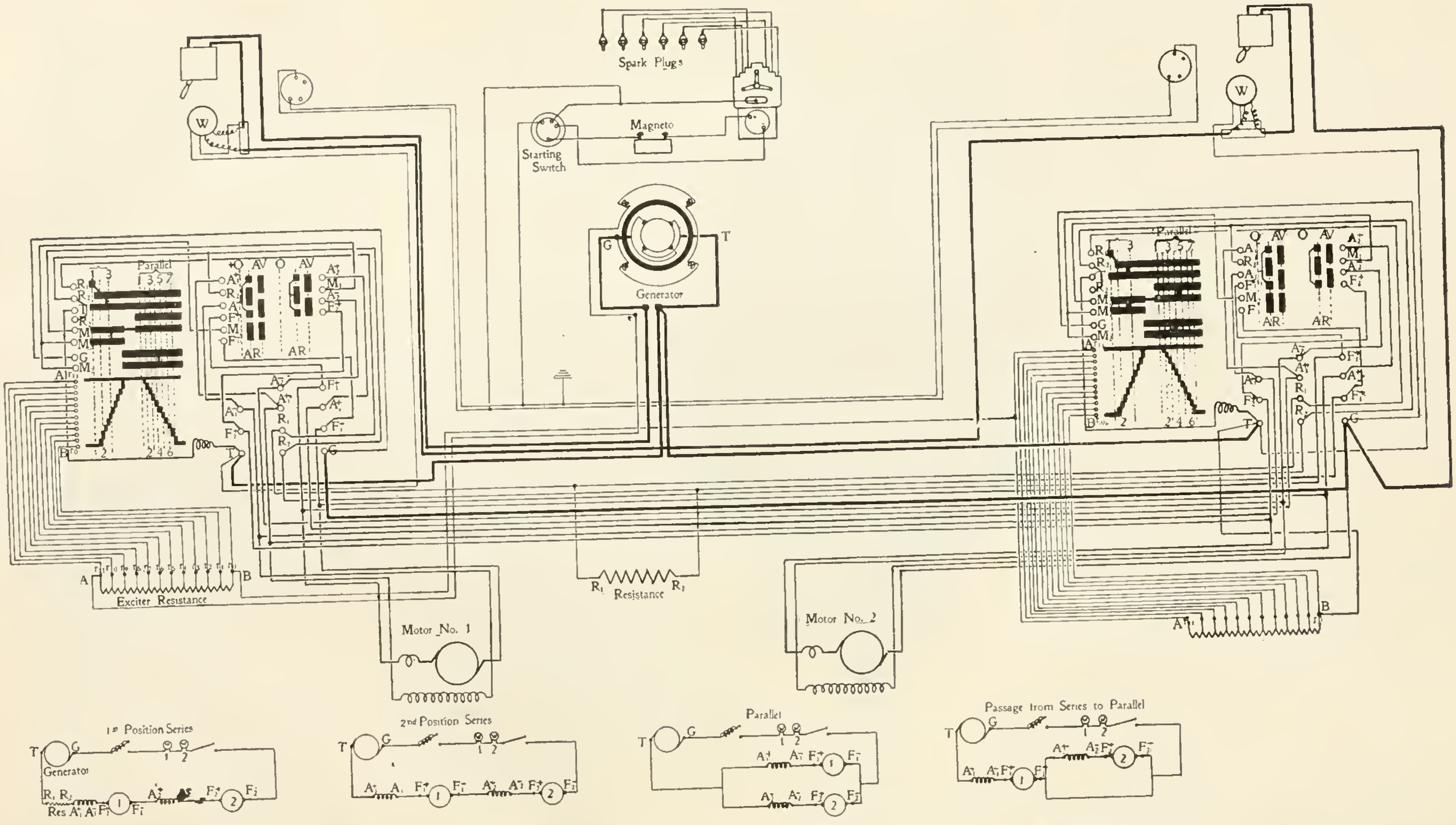

FIG. 8—DIAGRAM OF CONNECTIONS FOR GASOLINE-ELECTRIC AUTOMOTRICE

splendid economies for the lines operating. To secure greatest efficiency in serving the railways where they now have greatest need, a minimum weight, coupled with simplicity and low cost of maintenance, must be the watchword. A high speed automotrice would need more power, hence greater weight and resultant increased operating and maintenance expense. Within the lighter limits advocated, two and one-half to three car miles per gallon of combustible may be insured. At this economical point there is no danger of aggravated operating costs from threatened high price of combustible. So long as the mileage costs of crew are fifty or more percent higher than the cost of combustible, the automotrice has an enormous growing field before it. The oft repeated query as to maintenance costs has been thoroughly answered by the Hungarian road which has a mileage record total of 5 300 000 car miles, covering seven years with maintenance costs of less than three cents per car mile.

ABLE I--AUTOMOTRICE OPERATING EXPENSES ON THE ARAD-CSANAD RAILWAY, HUNGARY

		Dollars					Details of Operating Expenses in Dollars per train mile							
Year.	No. train miles with Automatrice service.	Passengers per train mile.	Receipts per train mile.	Expenses per train mile.	Profit per train mile.	Total receipts from passenger traffic.	Conductors and drivers.	Gasoline.	Oil and waste.	Helpers and sundry.	Lighting, heating and cleaning cars.	State taxes.	Maintenance.	perating expenses, steam passenger service.
1897	....	.....	.....	.....	.....	$208,722.36	.....	.....	.....	.....	.....	.....	.....	.....
1902	....	.....	.....	.....	.....	204,141.06	.....	.....	.....	.....	.....	.....	.....	.....
1903	67,017	.8078	.2156	.1313	.0843	228,085.03	.0221	.0259	.0068	.0169	.0010	.0409	.0177	.2626
1904	165,918	.8699	.2354	.1151	.1203	241,226.33	.0204	.0262	.0039	.0049	.0010	.0431	.0156	.2623
1905	192,499	.9632	.2630	.1197	.1433	267,549.48	.0221	.0237	.0039	.0075	.0006	.0447	.0172	.2633
1906	671,259	.7643	.2517	.1291	.1226	300,072.79	.0253	.0288	.0081	.0033	.0010	.0451	.0175	.2607
1907	895,089	.7270	.2659	.1456	.1203	320,551.62	.0288	.0341	.0065	.0036	.0016	.0476	.0234	.3021
1908	919,870	.7581	.2760	.1572	.1188	326,658.90	.0269	.0406	.0055	.0078	.0013	.0499	.0252	.3153
1909	882,798	.7395	.3233	.1670	.1563	385,473.13	.0328	.0328	.0049	.0078	.0019	.0581	.0281	.3252
1910	885,778	.8078	.3450	.1753	.1667	414,917.92	.0338	.0335	.0045	.0084	.0039	.0623	.0319	.3314
1911	952,143	.8264	.3457	.1732	.1725	439,065.43	.0344	.0366	.0033	.0075	.0023	.0626	.0265	.3132

SHOP TESTING OF ELECTRICAL APPARATUS

I—GENERAL INSTRUCTIONS

This is the first of a series of articles under this heading, describing in detail present day practice in the testing of various types of electrical apparatus.—[Ed.]

TESTS are made on electrical apparatus for two reasons, namely, to demonstrate or ascertain the effectiveness or correctness of design and to prove the quality of materials and accuracy of workmanship. The tests required on electrical apparatus are divided into four general sections:—Experimental tests, commercial tests, acceptance tests and special tests.

Experimental Tests are made on all machines of new design. While the design of electrical apparatus is based primarily on theoretical formulae, the designer would be hopeless without the constants derived from and based on extensive tests under actual operating conditions. Tests of this kind have been conducted over a period of many years on the various types of electrical machinery and it might seem as if the machines would be so standardized that it would not be necessary to repeat such tests. Electrical machinery is changing so rapidly, however, that it is necessary to continue tests and make new ones. As an example, the commutating pole machine, which is rapidly replacing the older types of machines, has revolutionized the testing of direct-current motors and generators. The development of high speed turbines has produced a similar condition with alternating-current generators.

Commercial Tests comprise the routine tests which are made on all electrical apparatus to determine whether the characteristics of the standard line are maintained in each individual machine and to be sure that no apparatus is sold which is defective in any part. It is much more expensive to correct defects due either to poor workmanship or defective material after the machinery has been shipped than it is on the test floor, in addition to which the manufacturing company is liable to suffer loss of prestige by failures of apparatus which might have been prevented by thorough tests. In general, commercial tests are not as elaborate as experimental tests.

Acceptance or Witness Tests—A great deal of electrical apparatus is sold under guarantees as to temperature, efficiency, power-factor, etc. In order to be certain that such guarantees have been met on large orders of apparatus, many operators either test electrical apparatus themselves after its purchase or send witnesses to oversee tests run by the manufacturers. Such tests are usually somewhat similar to commercial tests, but include such additional tests as are necessary to satisfy the requirements of the individual case.

Special Tests are run at the request of the manufacturer's engineers to determine special data. Such tests are indispensable to designing engineers, for new problems are continually being worked out, and improvements can be made only after tests on experimental designs. Empirical constants, based on the results of such tests, are in every day use by the designer.

THE USE OF METERS

Since the whole value of any series of tests depends upon their accuracy it is important not only that accurate and reliable measuring instruments shall be used but also that their characteristics and limitations be thoroughly understood, so that they may be used only under such circumstances that their accuracy will not be in any way impaired by surrounding conditions. The meters for each test should be selected and connected so as to give a deflection on the most accurate part of the scale, which is usually from 25 to 75 per cent of the full scale capacity. All meters should be in good working order with no tendency for needle to bind, and with the calibration recently checked. Meters in general use should be calibrated on all scales at least once a month, or oftener as the work may require, and should bear a card showing the date of the last calibration and the corrections to be made. The serial number of all the meters used on a test should be recorded on all test data.

When using a voltmeter with two or more scales, always first connect the leads for the high scale before placing the leads on the low scale. This will very often avoid damaging the meter in case the voltage should be higher than expected. Be very careful not to ground either of the leads, as this will frequently throw the full line voltage on the meter. Meters should always set level, since they are calibrated in this position; in any other position they may work sluggishly and may possibly read incorrectly, due to unbalanced moving parts. Nearly all meters are affected by stray fields unless especially built so as to be immune, and they should be placed at least six inches apart and at a sufficient distance from circuits carrying power so that they will not be affected by stray fields. This can be determined by taking a reading of the meter and then turning the meter around 180 degrees and taking another reading under the same conditions. The meter must be so located that it will show the same deflection for a given power in all positions before readings are taken. Where it is impossible to so locate the meter that the same power will show the same deflection in all positions of the meter, readings should be taken with the instrument set first in one position and then turned 180 degrees, and the average of the two readings should be considered as the correct reading.

Stray fields from ammeter leads can freqently be nullified by twisting the leads around one another. In order to get really satisfactory results, the operator should study the characteristics of his instruments and the principles involved, as no set rules can be applied to all cases.

Direct-Current Voltmeters and Ammeters—Most portable direct-current meters are of the permanent magnet moving coil or D'Arsonval type. Such meters have a uniform scale reading and are free from residual errors. The readings are dead beat, and the accuracy of calibration may be made extremely good over the entire scale. Due to the fact that they are of the permanent magnet type, such instruments cannot be used on alternating-current. They must not be used in close proximity to other meters or to current carrying leads, on account of stray fields. Where it is absolutely necessary to have two such meters near together, they should be placed end to end, with the scale ends adjacent, rather than side by side. Either magnetic or pneumatic damping is provided, what is known as critical damping being considered best; that is, damping sufficient to bring the pointer to rest in the shortest possible time when the voltage or current is suddenly applied. Ordinarily a meter in which the needle makes one and one-half complete swings before coming to rest meets this condition.

Alternating-Current Voltmeters and Ammeters—The alternating-current instruments in most common use may be divided into four general types, namely, the induction type, the Kelvin balance type, the moving coil type and the moving iron or magnetic vane type. With the exception of the induction type these instruments are all suitable for use with direct as well as alternating-current. In the induction and Kelvin types the deflection of the needle is in proportion to the square of the current, making the scale quite condensed for the first ten percent of the full scale reading but quite open over the rest of the scale. With the moving coil and moving iron types the scale is quite condensed at both ends and sufficiently open for accurate readings only between 25 and 75 percent of full scale. As previously stated most meters need to be carefully shielded from the effects of external fields; the Kelvin balance and the induction types are, however, almost entirely free from such effects. The general characteristics of these types of meters are indicated in Table I. In the case of alternating-current instruments which are liable to be placed on circuits where there is a tendency towards "pumping," there is an advantage in having the movements "over-damped," that is, having the damping so strong that it considerably increases the time required for the pointer to come to rest beyond that obtained by critical damping. Such a meter indicates the average of rapidly fluctuating voltages or currents and eliminates the effect of the pumping. Another advantage of over-damping is the protection afforded during short-circuits, as the movement is retarded sufficiently to greatly reduce the "kick" on the moving element. It should be remembered that in alternating-current meters, the torque of which is proportional to the square of the current, the effect of overload is much more important than it is with the D'Arsonval type meters whose torque increases only directly with the current.

TABLE I—ALTERNATING CURRENT AMMETERS AND VOLTMETERS

Type.	Induction.	Kelvin Balance.	Moving Coil.	Moving Iron or Magnetic Vane.
Initial Accuracy	Good	Highest	High	Good
Ratio of Torque to Weight	High	High	Low	Low
Ruggedness	Rugged	Rugged	Good	Good
Permanence	Best	Best	Fair	Fair
Frequency Errors	Slight†	None	None	Slight†
Temperature Errors	Slight	Slight	Slight	Slight
External Fields	Very slightly affected*	Not affected‡	Heavy shielding required	Heavy shielding required**
Convenience	Good	Poor	Good	Good
Scale	Great length	Great length	Short	Short
Scale Reading	Direct	Zero	Direct	Direct
Repairs	Simple	Simple	Not easy	Easy
Use on D.C.	Impossible	Correct	Correct	Conditional***

†Meter can be adjusted for accuracy at two frequencies, as 25 and 60 cycles, but is liable to be inaccurate at other frequencies. Only slightly affected by small variations in frequency.

‡Not affected by any stray field which influences all its coils equally.

*Affected by stray fields of same frequency only.

**Affected by any alternating or continuous stray field.

***Two readings must be taken, reversing the polarity between readings and taking the average as the correct reading.

Wattmeters in ordinary commercial use are of the induction, the Kelvin balance and the moving coil or dynamometer types. With the exception of the induction type they are equally accurate on alternating or direct-current, and their characteristics are in general quite similar to the similar types of alternating-current voltmeters and ammeters except that the scale divisions are uniform, being proportional to the product of the volts and amperes.

Special Meters—Portable frequency meters are used to a great extent for determining speeds of synchronous alternating-current apparatus, any type of frequency meter being suitable for this purpose. The vibrating reed frequency meter can also be used on any machine by having a make and break device mounted temporarily on the shaft in series with a direct-current circuit through the meter. For over-speed testing such an arrangement is especially useful as the instrument can be mounted at a distance from the machine being tested and all possible injury to the operator is avoided. Power-factor meters and graphic recording volt, ampere and wattmeters are frequently used, and the oscillograph is invaluable for much of the special testing.

In testing large machines the losses involved in the shunt and series coils of the meters from so small a percentage of the total power involved that they can be neglected entirely. In the testing of machinery of less than five horse-power capacity, the losses occasioned by the instruments may become appreciable, however, and it is necessary to take them into consideration. Since the voltmeter loss is usually constant in any given test, it is in most cases easier to connect the voltmeter behind the ammeters thus measuring the loss in the shunt coils, which can later be subtracted from the total power measured. In a similar manner the shunt coils of a wattmeter should be connected on the load side of the series coils and the loss involved subtracted. Certain types of wattmeters have automatic compensation for their own shunt losses. For ordinary work it is entirely satisfactory to make use of this automatic compensation, but where exact results are desired the compensating coil should be cut out and the proper correction made in calculating the results, as it is very seldom that the automatic compensation is exact. The correction for meter losses is much more important on transformer testing than on tests made on rotating machinery, not only because the quantities involved are usually smaller, but, as the load is of a non-fluctuating character, more exact results are possible.

Instrument Transformers—Current transformers should be selected so that their rated amperages correspond as nearly as possible to the currents with which they are to be used; the current should never be less than one-fourth or more than one and a half times the rated amperage of the transformer where accurate readings are required. The secondary load at rated amperage should not exceed the volt ampere rating, owing to ratio and phase angle errors introduced. Current transformers must not be used on circuits of more than ten percent below their rated frequency, unless specially calibrated for each frequency.

Voltage transformers should not be used on circuits of more than 35 percent above their normal voltage, nor of more than ten percent below their normal frequency. When using voltage transformers on frequencies more than ten percent below normal, use two transformers of the rated voltage with their primaries and secondaries each connected in series. Meter transformers should never be used on a test unless their correct ratio is known, since they are sometimes built with compensated secondaries for special meters.

TEMPERATURE TESTS

Temperature tests are measured by one of two methods, by thermometer and by increase in resistance. General temperature rises of conductors can be determined by a thermometer, which is usually much preferable, as the rise of resistance method only gives average values, and the temperature at some particular point may be somewhat higher than that indicated by this method. However, for large coils in which the conductor is deeply imbedded in the coil, and for high voltage armature coils in which the conductor is covered with a thick mass of insulation, the temperature of the outside of the coil is not a good indication of that at the conductor, and hence the rise of resistance method is more applicable. If the resistance of the circuit is quite low, however, thermometer measurements are frequently more reliable than measurements by the resistance method. The temperature should be measured after a run of sufficient duration for the apparatus to reach a practically constant temperature. This may be from two to twenty-four hours, according to the size and construction of the apparatus. It is permissible, however, to shorten the time of the test by running on over-load in current and voltage for a period of time not quite sufficient to bring the apparatus to its normal operating temperature, then reducing the load to normal and maintaining it thus until the temperature has become constant. In certain cases, such as shunt field circuits without rheostats, the current strength will be changed by a change of room temperature. The heat production may thereby be affected. Correction for this should be made by changing the observed rise in temperature in proportion as the I^2R loss in the resistance of the apparatus is altered owing to the difference in room temperature.

Thermometers should be carefully checked against each other, and examined for broken mercury columns before being placed on a machine. After examination, care should be taken that the thermometers are not inverted, as this is liable to break the column again. Never place the thermometer with the bulb higher than the other end. In placing thermometers on any part of a machine while the power is on, care should be taken that the natural ventilation of the machine is not interfered with, either by closing up the ventilating space or by placing too much packing over the bulb of the thermometer and thereby preventing the radiation of the heat generated inside of the coil or core. A general rule to follow is to allow one-eighth inch air space between the packing on the bulb of the thermometer and the part of the winding adjacent to it; for this purpose a pad made of one-eighth inch felt or a small ball of about three-quarters cubic inch of a paste made of oil and clay or gum, can be used to cover the bulb to protect it from the air.

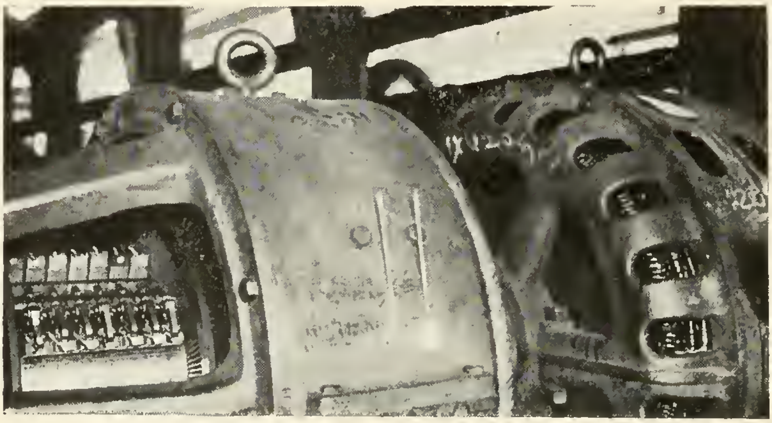

FIG. I—THERMOMETERS MOUNTED ON GENERATOR FRAME—BULB PROTECTED BY BALL OF CLAY (AT LEFT) AND FELT PAD (AT RIGHT)

When placing thermometers on the stationary armature copper of alternating-current machines or field coils of direct-current machines care should be taken that the felt pad, when used, is tied closely to the coil with string (not tape) in such a way that air from the machine cannot blow on the bulb. Where the curvature or the closeness of the coils prevents fastening the felt pad on the machine, use a small ball of gum, or a paste made of oil and clay, or a felt pad, as shown in Fig. 1, to cover the bulb. The surface of the bulb must be in contact with the coil and entirely protected from the air, and yet the natural ventilation of the machine must not be obstructed.

Two thermometers, one on each side at the top of the winding, should be placed on the stationary armature copper of all machines under ten horse-power. On all machines of over ten horse-power, at least four thermometers should be used, one on each side of the winding and on both sides of the yoke. Good locations for general usage are shown in Fig. 2.

At least one thermometer should be placed on the top of each of two field coils located above the horizontal center line and on opposite sides of the machine, as these are likely to be hotter than coils in the lower part of the machine. The thermometers on the stationary laminated iron should be protected from the air by gum or clay or a felt pad. The bulb should never be placed in the ventilating ducts while the machine is running, as the windage of the machine will give very unreliable results. On a running test do not place thermometers on the laminations too near the ribs holding the iron, since at times these ribs are hotter than the laminations themselves.

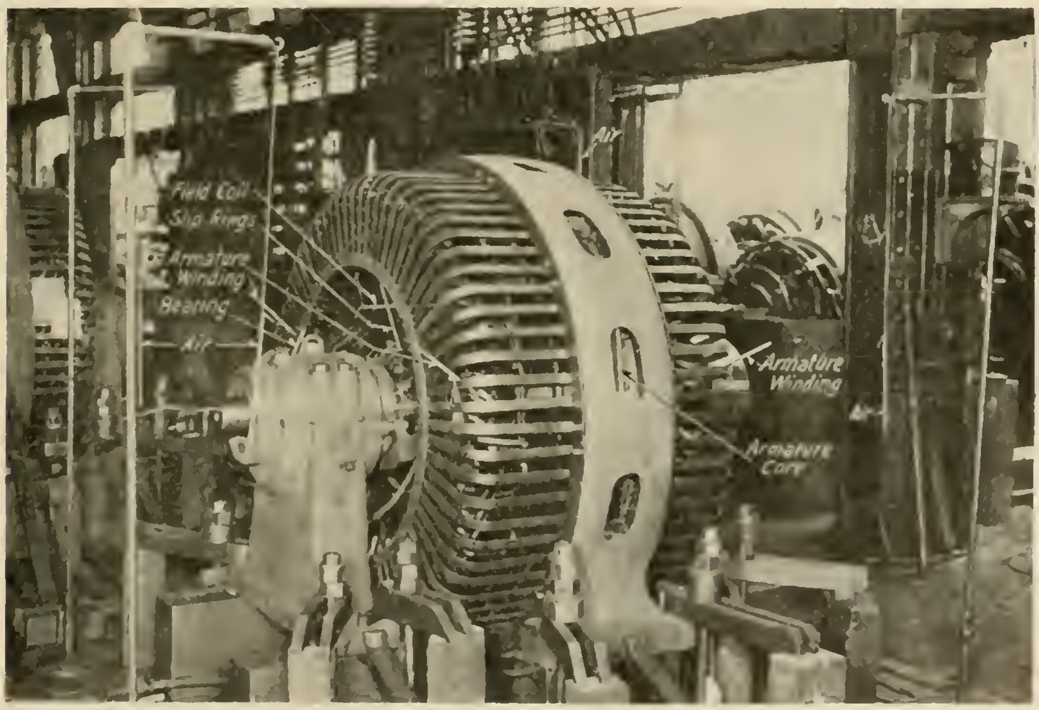

FIG. 2—GENERATOR ON TEST, SHOWING LOCATION OF THERMOMETERS

On machines up to 100 horse-power, at least two thermometers, one on each side, should be used on the laminated iron. Where it is impossible to put them directly on the iron, put them on that part of the frame which most nearly represents the temperature of the laminations. On the larger machines use five or more thermometers, placing two on each side, one on the top, and as many more as may be required.

Place thermometers in all bearings during running tests on all machines over 75 kilowatts, being careful that the movement of the oil rings is not interfered with. On machines under this rating feel the bearings by hand and note results on the test sheet. A limit of 35 degrees C. rise is allowed on all bearings, except on small enclosed machines where a rise of 40 degrees C. is permissible.

In taking the air temperature use the average of the temperatures taken during the last quarter of the run of tests of more than two hours duration, and the average of the last three readings on runs of less than two hours, as the final temperature to be used in calculating the temperature rise and also for correcting the hot resistance.

On small machines, place two thermometers, one on each side of the machine, so as to get the average temperature of the air going into the machine. On the larger machines place four or more thermometers around the machine in such positions as *will give the temperature of the air entering the machine.* These thermometers should not be placed over five feet from either side of the revolving part of the machine and should be in the same horizontal plane as the shaft and not over one foot from each side of the bearings. Any peculiar conditions in the air circulation should be noted on the test sheet. The ingoing air should be explored with a thermometer to see if any of the hot air coming from the windings is going directly back into the machine again. Usually the ingoing air will be along the shaft. On machines with enclosed end bells, the temperature of the ingoing air should be taken. The positions of the thermometers should be determined by the tester so as to get as nearly as possible the average temperature of the air entering the machine.

Temperatures After Shut-Down—Since there is no heat being generated in the machine after the power is cut off, the bulbs of all thermometers on any part of the machine, including those on during the running test must, after the shut-down, be covered with warm waste and well protected from adjacent parts of the machine so as not to be influenced by the temperatures of those parts. Enough waste must be used to cover the bulb and that part of the machine within two inches of the bulb. Take readings of all thermometers every two minutes until they reach a constant temperature.

Thermometers on the shunt or separate field coils should be placed on the top of at least two coils located above the horizontal center line and on opposite side of the machine, in as close contact with the actual copper as possible without disturbing the insulation on the coil; on machines with stationary fields these two thermometers are put on for the running test. Two additional thermometers should be placed on the coils at spots which are likely to be the hottest. When coils are of the sectional type, thermometers should be placed on the edge of the first section next to the yoke and also between the first and second sections.

Place thermometers on series and commutating pole field coils in the best manner possible, getting as much of the bulb in contact with the coils as possible. The thermometers should be placed on at least two coils above the horizontal center line of the machine on opposite sides of the yoke. When coils are of the ventilated type, place a thermometer between adjacent turns. Do not place thermometers too close to the joints of the coil, as these are usually uninsulated and are likely to be cooler than any other part of the coil on account of the better ventilation.

Place two thermometers on the revolving armature copper of all armatures under 75 kilowatts, one in the front and one in the rear, being careful to get in as close contact with the coils as possible, and pack well with waste. In machines over 75 kilowatts, use four thermometers, two in front and two in the rear, if possible getting those in the rear in between the coils. Do not put these thermometers too close to the armature iron, as the interchange of heat between the windings and the iron is very rapid.

On the revolving copper of induction motor, use two thermometers for machines under 50 horse-power. These must be placed as the motor comes to rest, as the rotor cools very rapidly. The bulbs should be in contact with the copper and well packed with waste. On machines of over 50 horse-power capacity use four thermometers, placing one on each side of the machine. Place two thermometers on the revolving armature iron of all machines, one in front and one in the rear, being very careful to get them on the iron and not on the fibre wedges holding the armature coils; pack well with waste. Place an additional thermometer on the armature iron from the inside of the spider when it is easy accessible. Pack all around thermometers on the stationary armature iron with warm waste after the machine is shut down. Whenever possible place an additional thermometer on the iron in the air-gap.

In addition to the above thermometers it is advisable to take the temperature of the iron in the ventilating ducts, since at times this part of the iron is hotter than at any other point. On field pole tips and dampers, and on squirrel cage dampers, take careful temperatures as these at times show a higher rise than the field coils. These temperatures are hard to get accurately, except on machines with large air-gaps, so that considerable care must be used in placing thermometers; pack well with waste and protect them as much as possible from the other parts of the machine.

For the commutator temperatures, waste should be well packed under the back of the carbon holders with the bulb of the thermometer placed under this waste, getting as close contact between bulb and commutator as is possible without touching the brushes. On machines of under ten horse-power rating use one thermometer; on machines rated from 10 to 100 horse-power use two thermometers, and on machines of over 100 horse-power use as many as may be necessary, placing them equidistant across the face of the commutator. Place thermometers on collector rings as carefully as possible and pack well with waste.

Speed Indicators—Numerous direct reading tachometers and speed indicators are on the market which give varying degrees of satisfaction. No one of them, however, can be considered quite as accurate as carefully counting the revolutions in a given time by means of a reliable speed indicator, and all of them are dependent upon a speed counter for calibration. The speed counter is quite familiar and its use is quite simple. A few precautions are necessary, however, in order to secure the best results. Care should be exercised that the axis of the speed counter is held in alignment with the shaft, as erratic results may be secured by holding it at an angle. A stop watch is not necessary, nor is an extremely accurate watch required. Any time piece which does not vary more than one minute per day should be satisfactory. Speeds should be counted through some definite period of time, one-quarter or one-half minute if only approximate results are desired, but not less than one minute for greater accuracy. It is not advisable to hold the point of the speed counter away from the shaft and endeavor to force it into contact at a given instant, as great accuracy is not possible in this way. The point of the speed counter should instead be placed in actual contact with the center of the shaft, but held from rotation by the thumb and finger. It is then possible to release the hold at any given instant with much greater accuracy. At the end of the given period the speed counter is at once pulled away from the shaft and its rotating element gripped with the fingers, this serving as a double check.

For fluctuating speeds some type of tachometer is quite convenient if not necessary. A standard form consists of a small magneto which is positively driven from the rotating apparatus through gears, a chain or flexible shaft. By inserting a suitable resistance in series with a voltmeter connected across its terminals the reading of the voltmeter may be made some even multiple of the revolutions per minute. This combination must be calibrated with a speed counter both before and after each test to insure accuracy, as the voltage of magneto is subject to fluctuations.

In the smaller portable tachometers that which is actuated by a single balance weight operated by centrifugal force is quite satisfactory and the calibration is much more permanent than in the types equipped with a double balance weight. The instrument is light and easy to handle, and if calibrated daily with a speed counter gives very satisfactory results. Liquid tachometers consist of a small centrifugal pump, pumping a light and usually colored fluid into a vertical calibrated glass tube, the static head being in proportion to the speed of the rotor. Like all other tachometers, this instrument is satisfactory only if calibrated quite frequently. It is not readily portable, and must be positively driven.

Testing Tables—Where tests are being repeatedly made, as in the testing department of a large factory, special testing tables wired with switches and instrument leads in convenient locations greatly facilitate routine testing.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM

FOR STEAM ROAD SERVICE

WALTER V. TURNER and P. H. DONOVAN,
Chief Engineer Mechanical Engineer
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This is the first installment of an admirable description of the latest practice in the design and operation of electro-pneumatic brakes, based on a paper read before The Franklin Institute by Mr. Turner, to whom was awarded The Elliott Cresson Medal by the Institute.—Ed.)

IT has long been known that electricity could add to the flexibility and efficiency of a compressed-air brake, but, so far as steam road equipment is concerned, there are four chief reasons why it has not heretofore been employed for this purpose:—

1—Electric current has not been available without special provision being made for it.

2—We have not had sufficient knowledge or material at hand to insure a reliable current and connections.

3—The present air brake has been sufficiently flexible and near enough to being simultaneous for the conditions up to quite recently.

4—The pneumatic brake had not been brought to such a degree of perfection as would warrant the application of electricity to it.

Now, however, current is available on practically all the steam trunk lines, as well as on electric railways, as nearly all first class trains are lighted by electricity. The art has developed into a science, in that reliable information and data are at hand with which to make practicable applications, and jumper connections have been brought to such a state of simplicity and reliability that there is no longer need for fear in these respects.

As affecting the action and results of the operation of the pneumatic brake, at least two serious changes in conditions have occurred;—the use of heavier vehicles and longer trains.

In addition to this, time has become much more important than heretofore because of the congestion of traffic, particularly in and adjacent to large cities, and because the time lapse as a factor in controlling trains composed of heavy vehicles with the pneumatic brake has become quite serious. The time element in the brake operation is very important in two ways. In one, it is very necessary, and in the other very undesirable. For service operations a time interval is necessary in some steps of the operation; for instance, while it is important that the brake commence to apply on each vehicle of a train simultaneously, it is equally important that the development of the force be obtained gradually and both for the same reason, namely, the elimination of damaging shocks and discomforting surges to or in the train. The simultaneous application prevents the slack from first running in and then out, and so on; while the slow rise of cylinder pressure prevents a too sudden and rapid change of motion, that is, deceleration with its consequent disagreeable effect upon the passengers. In emergencies the time element is very undesirable, as to stop is then the only consideration, the requirements being that the consequences be less disastrous than if the accident had not been avoided.

With regard to time so far as traffic is concerned, every second saved between stations means an increase in the number of passengers it is possible to carry on the same track, as well as a reduction in the schedule time, and consequently greater realization of the object of running a railroad.

With regard to the time affecting results of pneumatic brake operation, this is manifested with long trains in the increase of time necessary to get the brake applied, and by shocks and stresses, due to the different designs of brake apparatus, or force at the front and rear of the train, at the same instant, and the more rapidly it is attempted to apply the brakes (when rapidity does not include simultaneous action) the greater will be the shocks and stresses. Moreover, with passenger rolling stock developed to its present state or condition for the comfort of travelers, any shortcomings, or lack of improvements in this respect stand out very prominently by contrast, and this is particularly true of what is probably the only remaining two improvements to be made in modern trains, namely, eliminating the discomforts produced by the starting and stopping of these trains.

The application of electric current to the brake will not only eliminate the shocks and surges that occur with even the present slow service rate of brake application, but will permit the application to be made more rapidly throughout the train as a whole. This will be understood when it is considered that a train in motion is, in effect, a power plant, having kinetic energy, the utilization of which can be spread over many minutes, on the one hand, or condensed into a few seconds, on the other. That is, the train may be *permitted* to dissipate its energy in minutes or *compelled* to do it in seconds.

With regard to the fourth proposition namely, that the pneumatic brake has not until recently reached such a stage as would warrant its being actuated electrically, electricity would not add to the braking force, its purpose being to produce simultaneous operation; the application of the brake, in other respects, being identical with the ordinary pneumatic operations. The chief purpose in adding electricity to a pneumatic brake is to transmit the intent of the engineer or operator instantly to each vehicle of the train, thus eliminating shocks and stresses, both in service and emergency, and to shorten the emergency stop somewhat by producing instantaneous application of the brakes on all vehicles in the train.

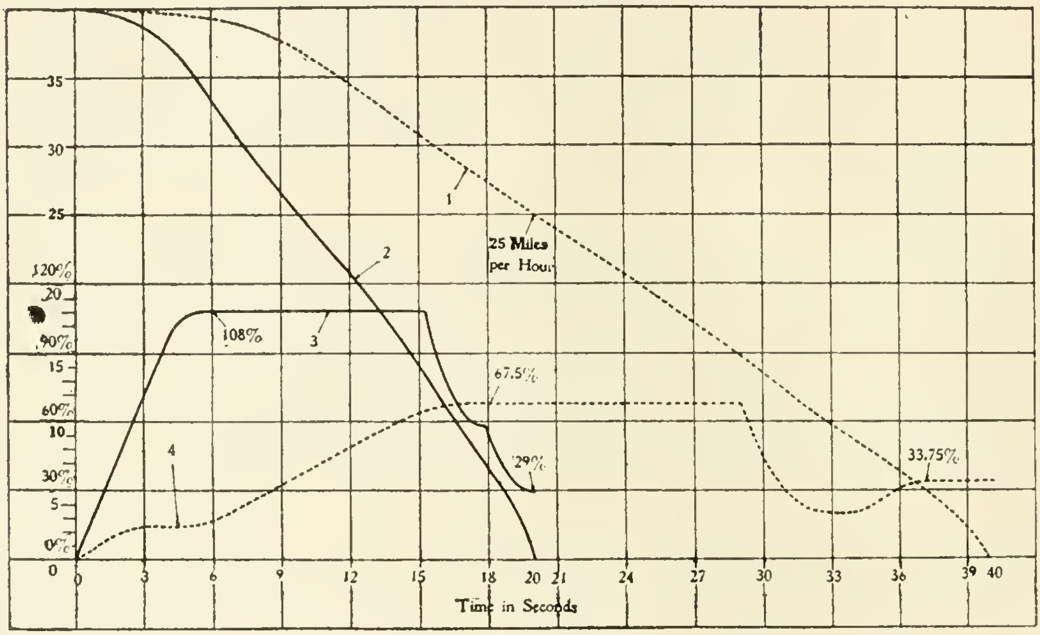

FIG. I—SPEED-TIME AND BRAKING CURVES, SERVICE APPLICATION

In the last year or two vehicles have become so large and heavy and trains so long because of large locomotives that the time element between the application and release of the brake from the engine to the last car has become a quite serious factor, since it permits the slack to run in or out, producing discomforting and sometimes dangerous shocks. Operating the service brakes electrically under such conditions will eliminate this, while, in emergency, it will serve the twofold purpose of preventing shocks and shortening the stops.

Before going into the design of the electro-pneumatic brake, it may be well to show some of its advantageous features and to emphasize the importance of improving the pneumatic brake to its highest degree, before adding electric features, by showing a few curves illustrative of the characteristics of the various improvements or changes in results. The advantages of the electro-pneumatic equipment over the strictly pneumatic equipment for service and emergency operation are shown in Figs. 1, 2, and 3.

The results shown on these curves represent service and emergency stops made from a speed of 40 miles per hour with a ten car train equipped with the electro-pneumatic brake and an eight car train equipped with the old style equipment. Curves *1* and *2* on each figure illustrate the relative decrease in speed as the stop is approached, and curves *3* and *4* show the relative percentage of braking power developed. The full line curves in each case represent the improved equipment, the dotted line curves the old equipment.

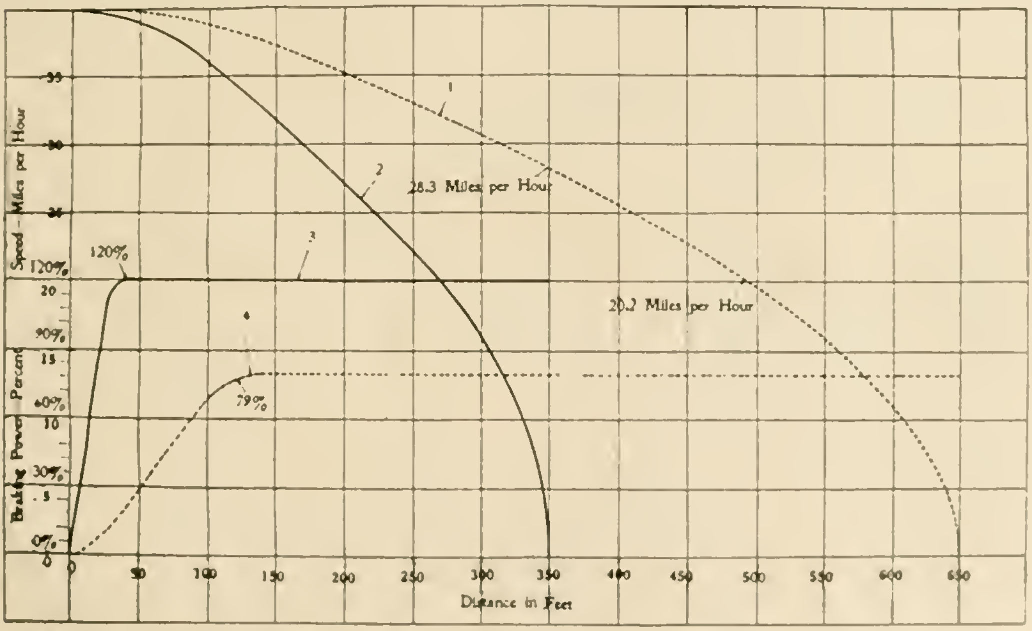

FIG. 2—SPEED-DISTANCE AND BRAKING CURVES, EMERGENCY APPLICATION

Fig. 1 represents comparative stops made with a typical service application of the brakes in each case. These curves are plotted on a *time* base to permit of more directly representing the *time saved* and *economy factor* of the electro-pneumatic equipment as compared with the old pneumatic equipment. It will be seen that with the average manipulation, characteristic of the two types of equipment, there is a saving of 20 seconds in the time of stop, in favor of the electro-pneumatic equipment. It will be evident that this shortening of time of the stops is due to the fact that a *higher braking power* is obtained in a *shorter time*, and that the service action is started *simultaneously* on each car, as compared with the old pneumatic equipment.

The high percentage of braking power is permissible with the electro-pneumatic equipment by reason of the great flexibility of this equipment; that is, the simultaneous action permits of a high braking force at the start, while the speed is high, and by means of the graduated release feature the braking force can be gradually reduced as the speed of the train decreases. With the old pneumatic equipment not having the graduated release feature the serial action in applying the brake, required different manipulations and would not permit of the use of high braking force if smoothness of stop was to be considered.

The maximum braking power with the new equipment (as shown by Curve 3, 108 percent) was obtained in about 4½ seconds, and was retained for about 11 seconds longer, or until the speed of the train had been reduced to about 14 miles per hour, after which the brake was graduated off, the train coming to a stop, with the braking power reduced to 29 percent. This curve may then be considered as a typical braking power curve showing the graduated release stop.

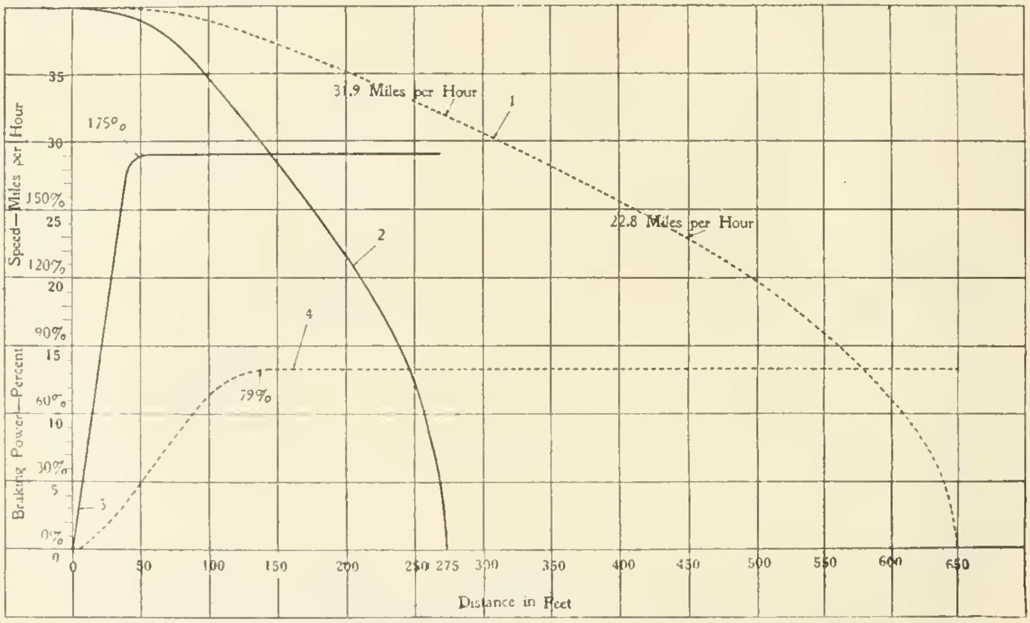

FIG. 3—SPEED-DISTANCE AND BRAKING CURVES, EMERGENCY APPLICATION

The maximum braking power with the old equipment, (as shown by Curve 4, 67.5 percent) was obtained after a lapse of 16 seconds and was retained for about 13 seconds longer, or until the speed of the train was reduced to about 14 miles per hour, at which time the brake valve was moved to release and back to lap, and then a second application was made, the train coming to a stop with the braking power about 33.75 percent. This curve may then be considered a typical braking power curve showing the usual two-application stop, which is the nearest approach to the graduated release possible with the old equipment.

It will be noted that at the time the ten car (electro-pneumatic) train has come to a stop, the eight car (old equipment) train is still moving at a speed of 25 miles per hour (62.5 percent of its initial speed), with about 39 percent of its original energy still remaining to be overcome before it can be brought to a standstill. This shortening in the time of stop makes possible higher speeds and shorter schedules, with consequent increased traffic capacity with the same number of cars and power consumption; or the same traffic capacity with fewer cars; or the same average speeds, schedules and traffic capacity with less power consumption, since the power may be shut off sooner and the train allowed to drift or coast for 11 seconds (645 feet) before applying the brakes to make the stop at the same point.

Even with this possibility of making service stops in a much shorter time, and thus increasing the traffic capacity of the system, there still remains the necessity of keeping the signals spaced the same distance as before, unless the emergency features of the brake are improved as well as the service. But with the emergency brake improved, and the ability to stop the train in a much shorter distance, as shown by the curves in Fig. 3, it is possible to decrease the distance between signals and still maintain even greater safety than before.

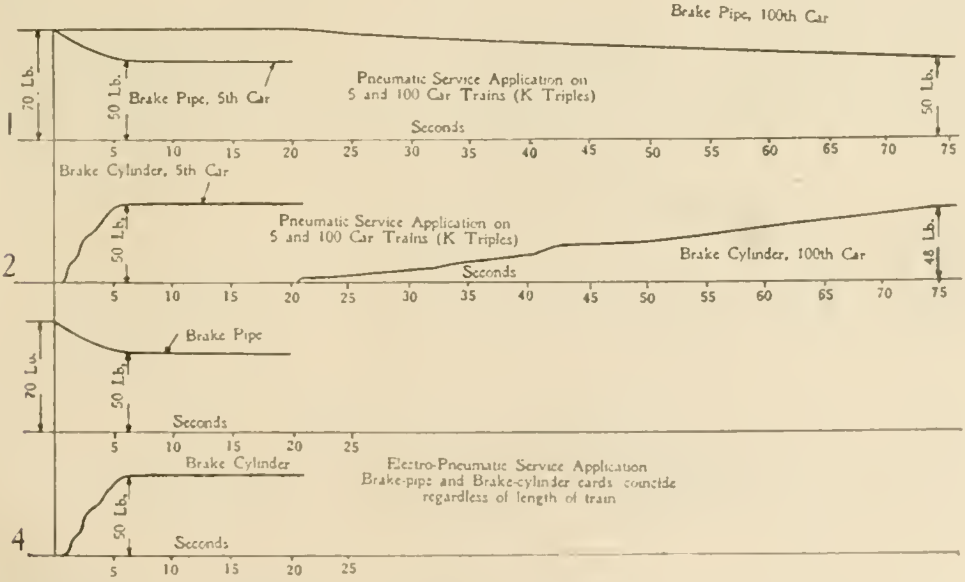

FIG. 4

It is possible then to not only run on a much less headway, and in some cases double the number of trains operating, but also longer trains may be operated, since, by the simultaneous and uniform action of the brakes, shocks and stresses are reduced to a minimum.

Fig. 2 represents comparative stops made with an emergency application of the brakes in each case. These curves are plotted on a *distance* base to compare the *length of stop* and relative *safety factor* of the two equipments. It will be seen that the stop with the train having the electro-pneumatic equipment is made in a much shorter distance and less time than that with the old equipment. At the *350 foot mark* where the electro-pneumatic train stopped, the other is moving at a speed of 28.3 miles per hour (71 percent of its initial speed), with 50 percent of its original energy still remaining to be overcome before the train comes to a standstill. At the *time* the electro-pneumatic train stopped, the old equipment train has run 140 feet farther and is still moving at a speed of 20.2 miles per hour, representing 25.5 percent of its original energy. This shortening of the stopping distance with the electro-pneumatic train results from the increased percentage of braking power over that obtained with the old equipment train and also from the fact that *simultaneous* emergency action is obtained throughout the train, as against *serial* action with the old equipment.

The maximum braking power in the old equipment train was only 79 percent, and was obtained at about 150 feet from the point where the brakes were applied; while 120 percent braking power was obtained in the electro-pneumatic train after it had run about 40 feet from the point where the brakes were applied.

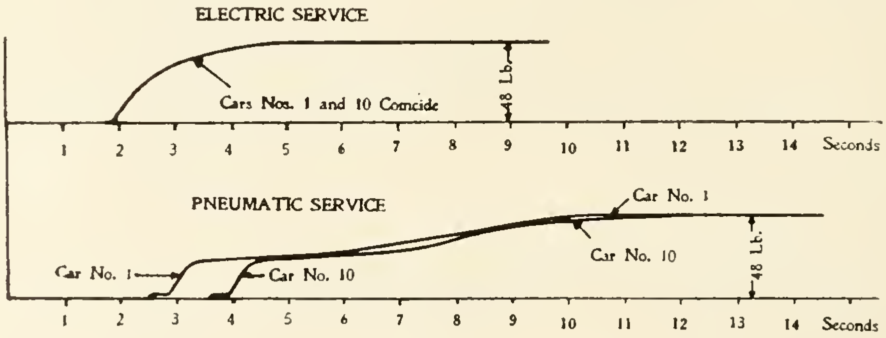

FIG. 5

Fig. 3 represents comparative stops made with an emergency application of the brakes on an eight car old equipment train and a ten car train equipped with the most improved electro-pneumatic brake (main reservoir pressure used in emergency).

The maximum braking power obtained with the improved electro-pneumatic equipment is 175 percent, as against 79 percent with the old equipment. The latter train ran 650 feet before coming to a stop, while the former train was brought to a standstill in 275 feet. As the old equipment train passed the point where the improved electro-pneumatic equipment train stopped, it was running at a speed of 31.9 miles per hour (79.75 percent of the initial speed, with 63.5 percent of its original energy) and at the time the improved electro-pneumatic train was brought to a stop, the old equipment train was still running at the rate of 22.8 miles per hour (57 percent of its initial speed) with 37.5 percent of its original energy remaining).

By comparing the curves for the electro-pneumatic equipment and the improved electro-pneumatic equipment, it will be seen that the braking power for the latter is greater than the former by 35 percent and its stopping distance is 75 feet shorter. This is due to the fact that main reservoir pressure (approximately 100 pounds) is obtained in emergency operations, thus giving the high braking power.

To further show the immense value and powerful effectiveness of the improved form of electro-pneumatic brake, the following might be added:—The ten car train, weighing 331 tons and running at a speed of 40 miles per hour, has a kinetic or "wrecking" energy of 17 800 foot-tons, equivalent to raising a ton weight to the height of 17 800 feet, or to raising the whole train to a height of 54 feet. This energy is entirely dissipated by the brake and the train brought to a stop in 9.25 seconds, and in a distance of 275 feet from the point where the brakes were applied.

In Fig. 4 diagram 1 illustrates the great difference in the rate of brake-pipe reduction between a 5 car and a 100 car train when making a pneumatic service application. Comparing the results obtained from the two trains, it will be seen that with the 5 car train the brake pipe reduction started immediately, and in six seconds time a 20 pound reduction was obtained; while with the 100 car train the reduction did not start until 20 seconds time, and it required 75 seconds to obtain a 20 pound reduction. Diagram 2 shows the rise in brake cylinder pressure resulting from the brake pipe reduction shown in Diagram *1*, and is proportional thereto. Diagram *3* shows the drop in brake pipe pressure, and Diagram *4* shows the rise in brake cylinder pressure resulting from an electro-pneumatic service application. Since the electro-pneumatic operation is simultaneous, the same brake pipe and brake cylinder cards would be obtained on every car in the train, regardless of the length of the train.

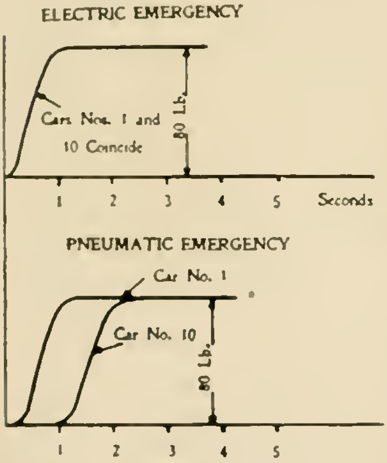

FIG. 6

The advantages of the electro-pneumatic equipment are clearly shown here, as the time element is entirely eliminated, resulting in each car starting to do its share of braking simultaneously. This simultaneous action of the brake eliminates the disastrous results due to the slack between the cars.

Two diagrams are shown in Fig. 5, the upper diagram illustrating an electro-pneumatic service brake application, showing the start of rise in brake cylinder pressure in 1.9 seconds and the maximum cylinder pressure obtained in 5.5 seconds, and all brakes applying simultaneously. The lower diagram shows the results obtained from a pneumatic service brake application on a ten car train. The time for starting the rise in brake cylinder pressure was 2.75 seconds, and the time for obtaining the maximum brake cylinder pressure was 11 seconds. The difference in time between the first and tenth cars, in start of rise in brake cylinder pressure, was one second.

Two diagrams are shown in Fig. 6, the upper diagram illustrating the results obtained from an electro-pneumatic emergency application on a ten car train. The lower diagram shows the results obtained from a pneumatic emergency application on a ten car train. Comparing these diagrams, it will be seen that the only difference is in the time of transmission.

In the diagrams shown in Fig. 7, the upper curves illustrate the results obtained from a pneumatic emergency application with the "PC" equipment. The maximum brake cylinder pressure was obtained in 2.8 seconds, resulting in a braking power of 180 percent. The lower curves show the results obtained from a pneumatic emergency application with a double "PM" equipment, (a complete brake equipment for each truck.) The maximum brake cylinder pressure was obtained in 5.6 seconds, resulting in a braking power of 114 percent. These curves graphically illustrate the great difference that exists between different equipments, and that greater gain can be had by improving the pneumatic portion of the brake than by adding the electric features to the old equipment.

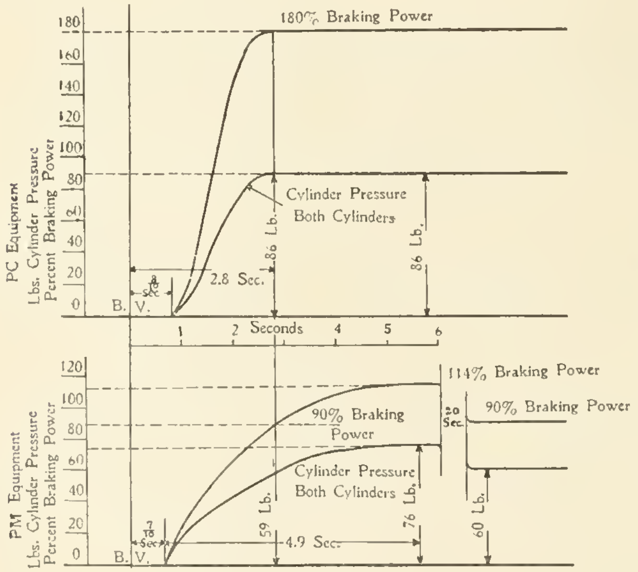

FIG. 7

In order to compare the two equipments, the stopping of two ten car trains running at 60 miles per hour will be considered, the energy in these trains being 120 foot tons per ton weight. The train equipped with "P C" equipment will stop in 575 feet shorter distance than the train equipped with the "P M" equipment. If the train having the "P M" equipment had the electric features added, without any other improvement, the stop would be shortened only about 70 feet; therefore, the stopping distance would still be 500 feet longer than with the train equipped with the latest improved automatic features. This is because adding the electric features merely eliminates the time of transmission, the greater benefit being the prevention of serious shocks and break-in-twos.

(*To be Continued*)

SWITCHBOARDS FOR ALTERNATING-CURRENT POWER STATIONS—GENERAL

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THERE are three distinct classes of switchboards which are suitable for alternating-current stations:—The "self-contained" panel type, hereinafter called "Class 1", the "remote mechanically controlled" called "Class 2", and the "electrically operated", called "Class 3."

Class *1* includes those switchboards in which all apparatus is mounted on the panels; Class *2*, those in which the main current carrying parts are mounted apart from the board with main switching devices mechanically controlled by means of levers on the panels; Class *3*, those in which the switching devices are operated by solenoids or motors, or, in a few cases, by a combination of solenoids and compressed air, known as electro-pneumatic operation. The classes are illustrated in Figs. 1, 2 and 3.

The question often arises as to the dividing line between these three classes. This can only be answered in a general way. There are many instances in which but one of the three classes seems applicable. There are also many instances in which any one of the three could be applied with good results. In a large number of instances, however, the advantages are so equally balanced that the dividing line becomes, in reality, a broad belt of uncertain width, increasing in advantage for one class or the other near the edges.

The principal factors influencing a choice of one over the other two classes are:—Power to be handled, essential operating features, space required, and permissible cost. A comparative discussion of the three classes as regards these factors may, therefore, be of some assistance to those who have to make a choice.

CAPACITY TO BE HANDLED

The capacity of a station determines the class of switching devices which may be used, which in turn, usually determines the class of switchboard to be employed. Oil switches and circuit breakers are given an ultimate breaking capacity rating just as they are given a current and voltage rating. These ratings are determined by three characteristics; namely, the insulation for a given voltage, the size and arrangement of the current carrying parts for a given current rating, and the ability to withstand the severe mechanical stresses due to the explosive effects of short-circuits.

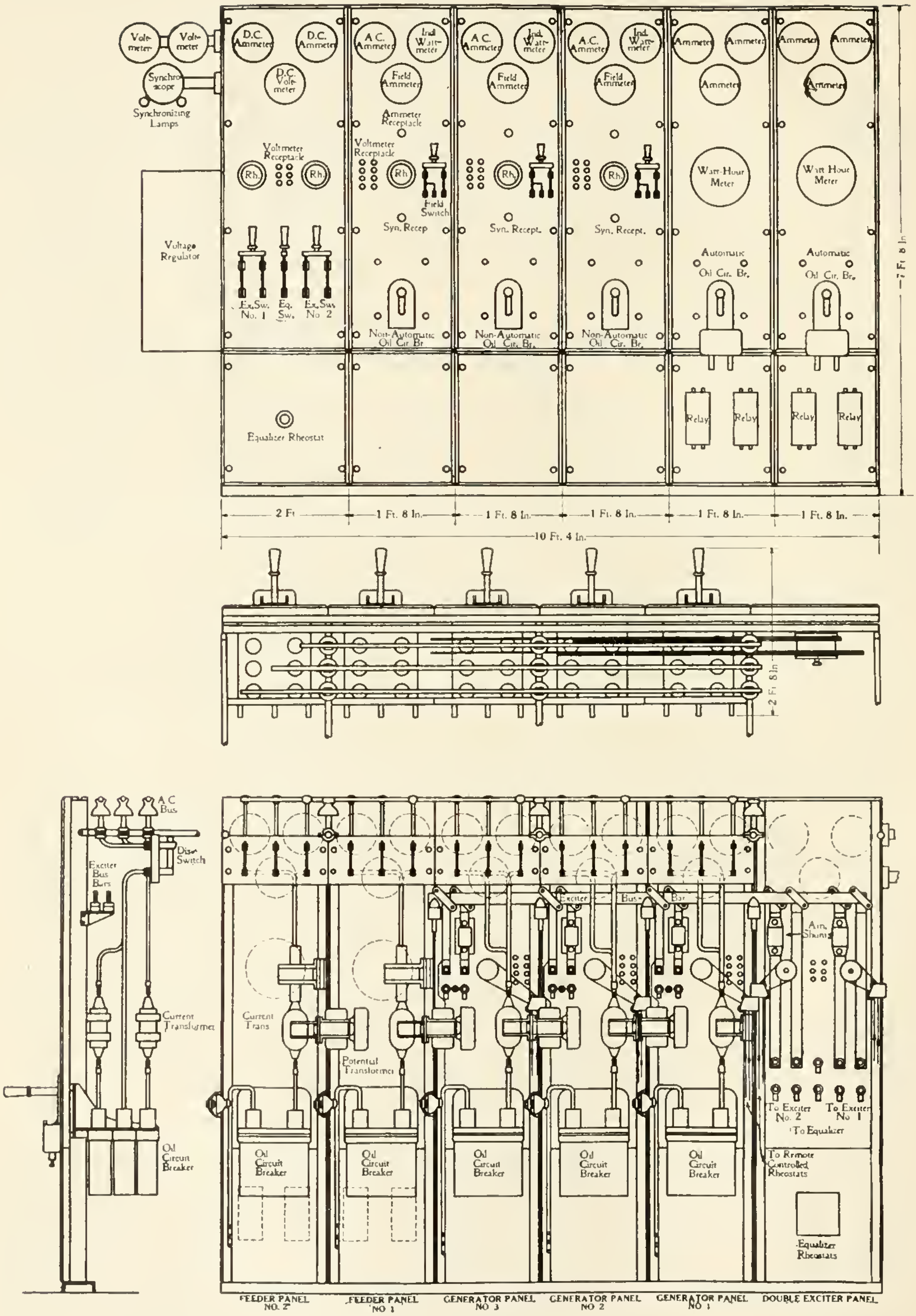

FIG. 1—SWITCHBOARD OF SELF-CONTAINED TYPE (CLASS NO. 1) FOR TWO EXCITERS, THREE GENERATORS AND TWO FEEDERS

All apparatus except rheostats mounted directly on panels.

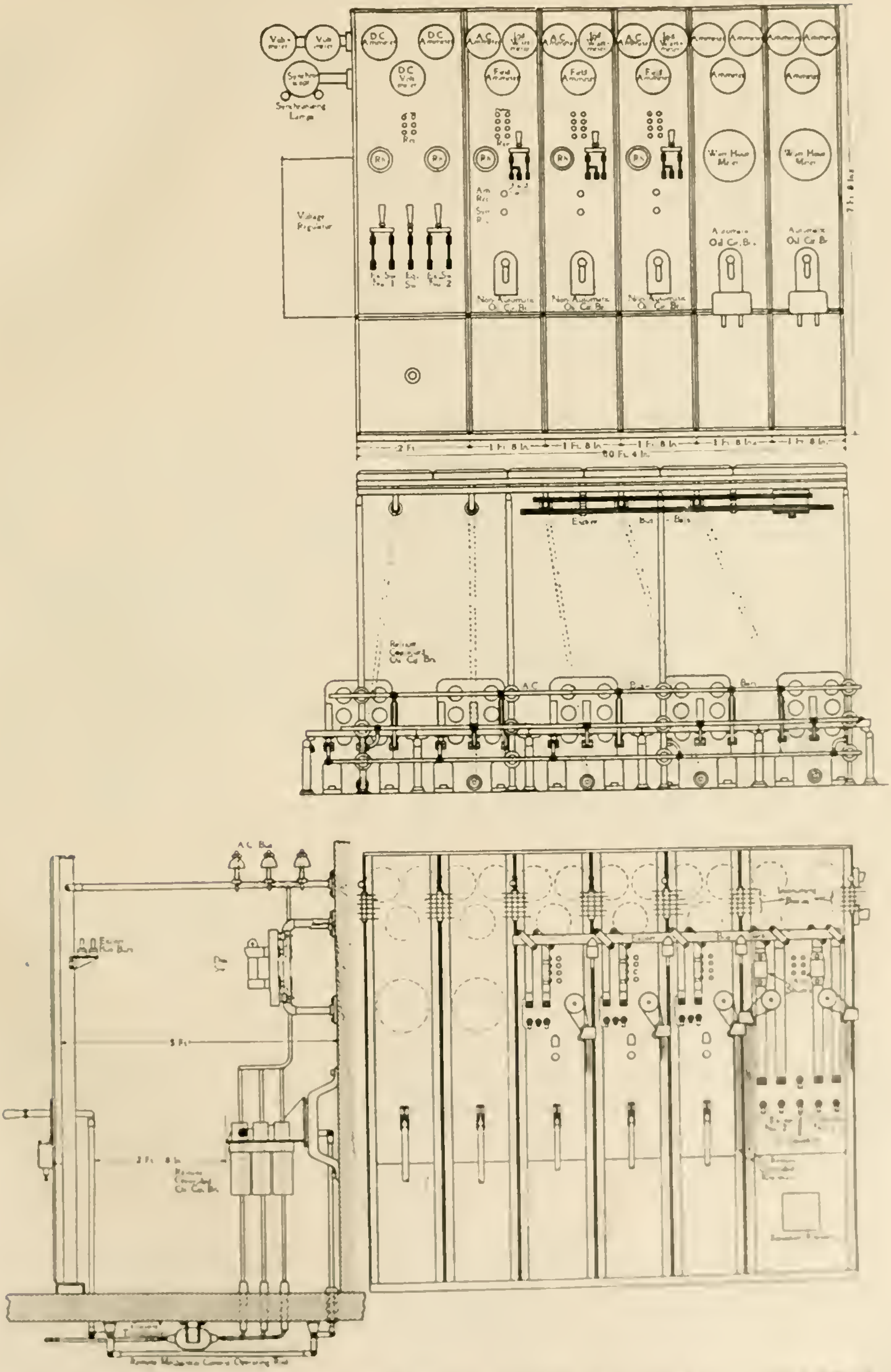

FIG. 2—MECHANICALLY OPERATED REMOTE CONTROL SWITCHBOARD, CLASS NO. 2

All alternating-current control apparatus is mounted apart from the switchboard. When this class of board is of the remote control self-supporting type, the apparatus can be mounted on a separate framework, apart from the board, and can be located in a separate room above, below or behind the switchboard, the distance being limited by the weight and inertia of the mechanical connections to the circuit breaker.

The ultimate breaking capacity of a circuit breaking device, therefore, depends primarily on the dimensions and proper association of those parts which must bear the stresses due to opening under short-circuit. The amount of power which the circuit breaker set for instantaneous tripping must interrupt, in case of short-circuit, is not that indicated by the nominal rated capacity of the station, but the maximum instantaneous power which the generators are capable of delivering. Modern high speed generators give from ten to twenty times full-load current for the first few cycles of a short-circuit. Some manufacturers permit even higher values, instances of fifty times full-load current on short circuit being reported.

The ultimate capacity ratings of circuit breakers are now usually based on automatic instantaneous overload tripping in connection with turbogenerators having approximately six percent inherent reactance, and of the maximum rated voltage given for the circuit breaker. The circuit breakers are considered as connected direct and close to the source of power. If the reactance of the generators is lower than six percent, external reactance should be supplied to limit the flow of current on short-circuit unless there are but a few machines of moderate capacity connected to the sys-

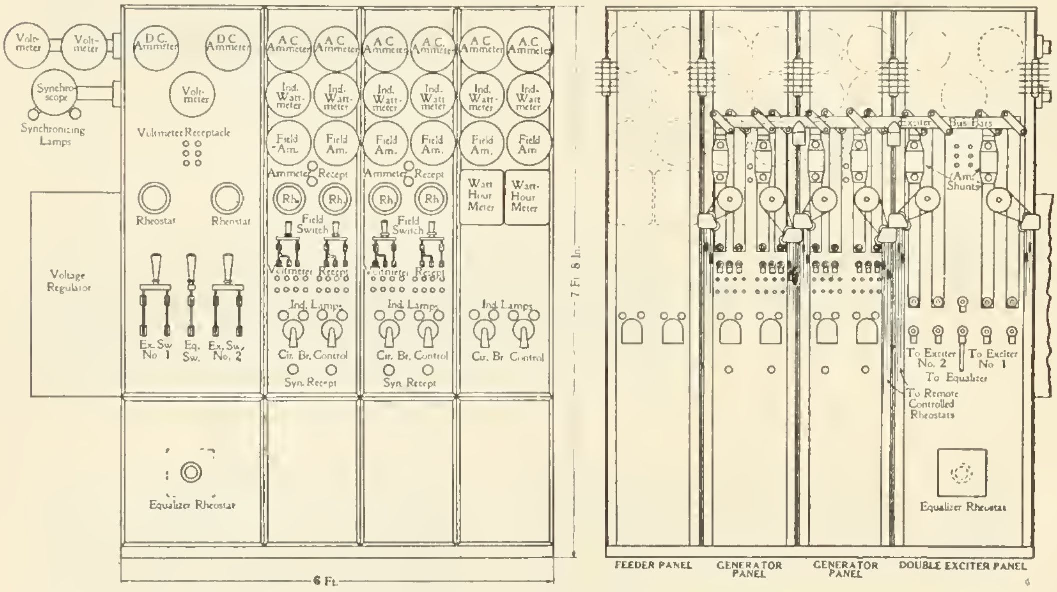

FIG. 3—ELECTRICALLY OPERATED REMOTE CONTROL SWITCHBOARD, CLASS NO. 3

This board is arranged for controlling one more generator than the board shown in Figs. 1 and 2, but the switchboard is much shorter. The remote controlled structure for switchboards of this type and capacity, when similar switching equipment is used, look very much like the remote controlled structure shown in Fig. 2. The electrically operated board, however, is usually of much greater capacity than either of the other types and the switching equipment is therefore usually mounted in a separate masonry or concrete compartment.

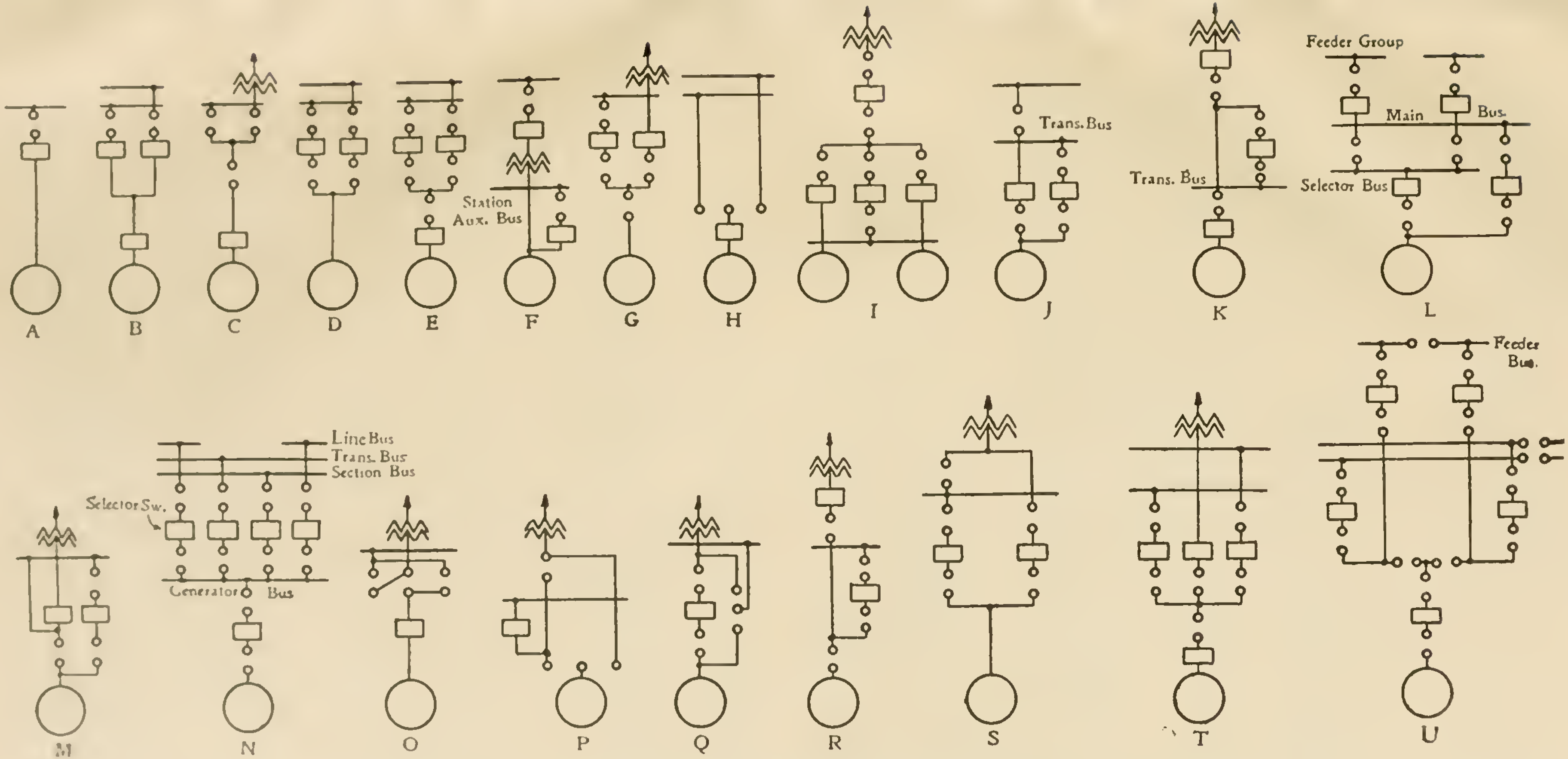

FIG. 4—TYPICAL CONNECTIONS BETWEEN GENERATOR OR MOTOR AND BUS-BARS

As practically all of these connections also apply to feeder or line circuits, they may be regarded as the elements of diagram construction. Following is a list of typical power stations employing above schemes:

A { Central Colorado Power Company
Cleveland Electric Illuminating Company
Schenectady Power Company

B { Union Electric Light & Power Company,
St. Louis
Philadelphia Electric Company

C — Portland Railway & Light Company

D { Southern California Power Company
Milwaukee Electric Railway & Light Co.
Illinois Steel Company
[illegible] Plant

E { Southern Pacific Railroad Company
Interboro Rapid Transit Company

F — Homestake Mining Company
G — Washington Power Company
H — Ford Plate Glass Company
I — Mt. Hood Railway & Power Company
J — Pittsburgh Railways Company

K { Central of Georgia Power Company
Pennsylvania Water & Power Company

L — Commonwealth Edison Company, Chicago

M — Rio Janeiro Tramways, Light & Power Company
N — Commonwealth Edison Company, Chicago
O — Washington Water & Power Company
P — Sanitary District, Chicago
Q — Kern River Power Company
R — Central of Georgia Power Company
S — Shawinigan Falls Water & Power Company
T — Ebro Irrigation & Power Company, Ltd. (Barcelon, Spain)
U — Stockholm (Sweden) Municipal Plant

tem. As the reactance of slow speed engine type machines is usually at least double that of the turbo-generators, the breaking capacity rating of circuit breakers, when used in connection with them, may be doubled.

Oscillograph records show that the first rush of current on a short-circuit falls off to about two or three times full-load current at the end of one and one-half to two seconds. Therefore, a circuit breaker provided with relays having a definite time limit setting of two or more seconds may be given double or triple its normal rating, depending on whether the units are turbo-generators or slow speed engine-type generators. Non-automatic circuit breakers may be given two, or three, or even four times the rating given for instantaneous automatic tripping, depending on the nature of the units, as the first rush of current will be over before the station attendant can trip the circuit breakers.

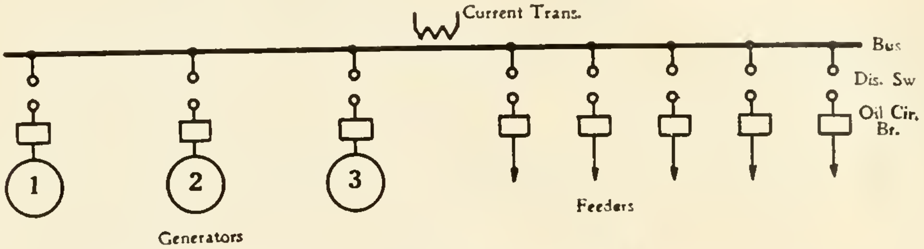

FIG. 5—SINGLE BUS SYSTEM

Used for small stations where simplicity and economy are of primary importance.

The protection of sub-stations or tie lines between stations presents still another problem in rating. As in the case of added reactance for generators in the shape of reactance coils, all reactance added by transmission lines, transformers or in any other manner, will increase the circuit breaking capacity rating in direct proportion to the reactance on which the maximum rating of the circuit breaker is made. For example, nine percent reactance in a transmission line with its step-up and step-down transformers will permit a rating two and one-half times normal for the low tension sub-station circuit breakers.

When circuit breakers are to be used on the secondary of a step-down transformer some distance from the source of supply, and the capacity of the transformer is small in comparison with that of the source of supply, the reactance of the transformer and the characteristics of its secondary circuits are the only factors which need be considered in determining the breakage capacity required.

When circuit breakers are used on lower voltages than the maximum at which they are rated, the ultimate current breaking capacity may be increased one percent for each percent decrease in voltage.

Reactance Coils—By the use of current limiting reactance coils at various points in the system the ultimate capacity ratings of the circuit breakers at those points may be decreased in direct proportion to the reactance employed. It is possible in this way to use circuit breakers on a system whose ultimate capacity is far in excess of their rating. It may be advisable in some cases to use the combination of reactance coil and small circuit breaker rather than a larger breaker because of space and cost considerations, and in order to reduce the strains on all parts of the system due to great rush of current to a short-circuit. Moreover, without the use of the coils there is always present the danger that a heavy short-circuit will open up the main circuit-breakers, instead of the individual feeders affected, thus shutting down possibly an entire system. It is this selective action obtained by the use of reactance coils, cutting out only the feeder affected, which makes for ideal operating conditions.

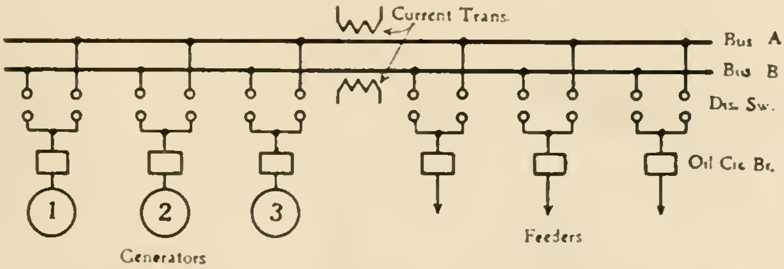

FIG. 6—DOUBLE-BUS SINGLE CIRCUIT BREAKER SYSTEM

This arrangement greatly increases the chances for continuity of service over that shown in Fig. 1. One bus-bar may be used as an auxiliary only, or one may feed a lighting load while the other feeds a power load.

Reactance coils are frequently placed in the generator circuits to limit the flow of current on short-circuit and thereby to decrease the harm done to a machine from internal short-circuit by the remaining machines connected to the bus-bars, as well as to limit the station output in case of external short-circuit. This disposition of the reactance, however, does not eliminate the drain on the system caused by a short-circuit, does not provide the selective operation above mentioned and does not materially decrease the strains on the circuit breakers.

The ideal location of these coils is shown at *A*, Fig. 14. If, however, the cost is prohibitive or space will not permit, coils may be located at *B*, which will protect the group of feeders. The third alternative would be to locate them at *C* or at *D*.

Classification of Circuit Breakers,—The usual classification of circuit breakers in general commercial use is shown in Table I. Any

TABLE I

Cost, Percent*	Volts	Amperes	K.v.a. Capacity†	Type	Design
5.4 7.6	4 500 7 500	300 300	2 600	Switchboard mounted	Single frame. Single tank for all poles
9.8	7 500	500	5 000	Switchboard mounted or remote mechanical control	
12	15 000	300	5 000	Switchboard mounted or remote mechanical control	Single frame. Separate tank for each pole
49 19 16	2 500 6 600 13 200	2 000 1 200 600	7 500		
54 28 25 23	66 00 12 000 16 500 25 000	2 000 1 200 600 300	12 500	Remote mechanical control or electrically operated	
33 25 20	6 600 11 000 15 000	12 00 600 300	12 500		
76 65 54 49 43	15 000 15 000 15 000 25 000 35 000	3 000 2 000 1 200 600 300	25 000		Each pole a separate unit with its own frame and tank. Designed for wall or cell mounting.
100 95 95	15 000	1 200 600 300	40 000	Electrically operated	Single frame or base for operating mechanism. Separate tank per pole. Cell mounting
260 215 136 126 116 116	13 000 15 000 25 000	4 000 3 000 2 000 1 200 600 300	60 000	Electrically operated	
73 107 176 259 500	44 000 66 000 88 000 110 000 150 000	300	60 000	Electrically operated	Each pole a separate unit. Designed for open mounting on floor
	6 600 to 25 000	1 200 600	200 000	Electrically operated	Single base, separate tanks, reactance coil per pole. Cell mounting
	44 000 66 000 88 000 110 000	600 and 300	200 000	Electrically operated	Each pole a separate unit. Reactance coil per pole. Designed for open mounting on floor

*Approximate relative cost for 3-pole circuit-breakers without relays or transformers.

†Ultimate breaking capacity in k.v.a. three-phase. For single-phase use 70 percent and for two-phase use 140 percent of values given.

The last two designs given in the above table are known as the reactance type breakers. Their great ultimate breaking capacity is obtained by opening the circuit on reactance coils, by means of an auxiliary contact, just before the main contacts open. There is no apparent reason why this type of circuit breaker cannot, by properly proportioning the reactance, be made to open any capacity safely.

circuit breaker given in the Table may be obtained in the remote mechanical control design, or arranged for electrical operation, or both, but they are here classified according to the usual practice.

Rating of Switchboards.—The capacity which a switchboard will safely handle depends upon the capacity of the circuit breakers employed, and the association of the various items, circuit breakers, bus-bars, instrument transformers, interconnections, etc., which comprise the switching equipment. Experience has demonstrated that there are certain limits of capacity above which automatic circuit breakers should not be mounted directly on switchboards. These limits vary considerably, according to the conditions of the installation, but in general it is recommended that no circuit breaker in capacities above 600 amperes, or above 2 500 volts, be mounted directly on the switchboard and that no self-contained type of board be employed for a station whose capacity is more than 2 500 k.v.a. three-phase in high speed turbogenerators, or the equivalent in low speed generators or other source of supply.

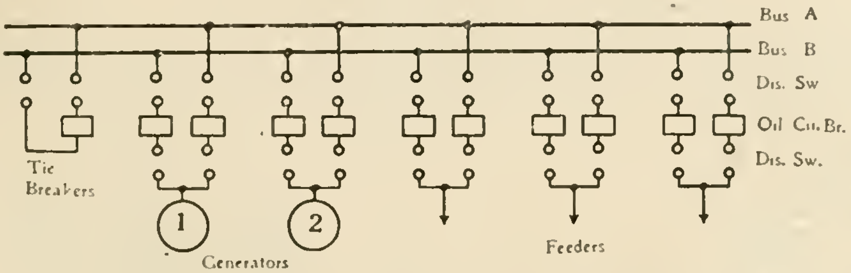

FIG. 7—DOUBLE BUS, DOUBLE CIRCUIT BREAKER SYSTEM

This arrangement gives the same advantages as Fig. 6, with double assurance against shut-down from circuit breaker trouble.

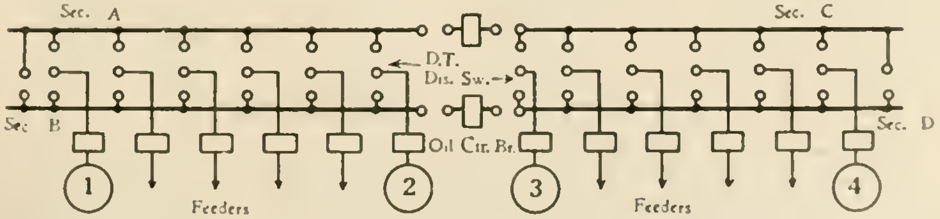

FIG. 8—RING BUS SYSTEM, BUS SECTIONALIZED

Suitable for stations of medium size where great flexibility and maximum economy in cost is desired. This arrangement requires a very small amount of copper in the bus-bars.

The remote mechanical control switchboard is limited in capacity by the physical rather than the electrical characteristics. Practically all high capacity circuit breakers are arranged for mechanical as well as electrical operation, but the mechanical control switchboard is confined to the use of those circuit breakers whose size is such that the individual mechanical parts ,and the mechanical arrangement as a whole, conform with good engineering practice. Therefore, it is recommended that this type of switchboard be confined to the use of circuit breakers of 3 000 amperes or less, and of 35 000 volts or less, and to stations whose capacity does not exceed 25 000 k.v.a. in high speed turbogenerators or the equivalent in other means of supply. The electrically operated board is, of course, unlimited as to capacity.

ESSENTIAL OPERATING FEATURES

The capacity of a power station, present and future, having been determined, the next step is the decision as to the number and size of units to be used, and the scheme of switching connections which will give the desired operating features. Figs. 4 to 17 illustrate a number of the more important and more commonly used arrangements with explanations of their principal features. A single line diagram of the main connections should be made, similar to one of those shown, with every machine, transformer and feeder shown connected in. This diagram will serve as a basis for the switching equipment specifications.

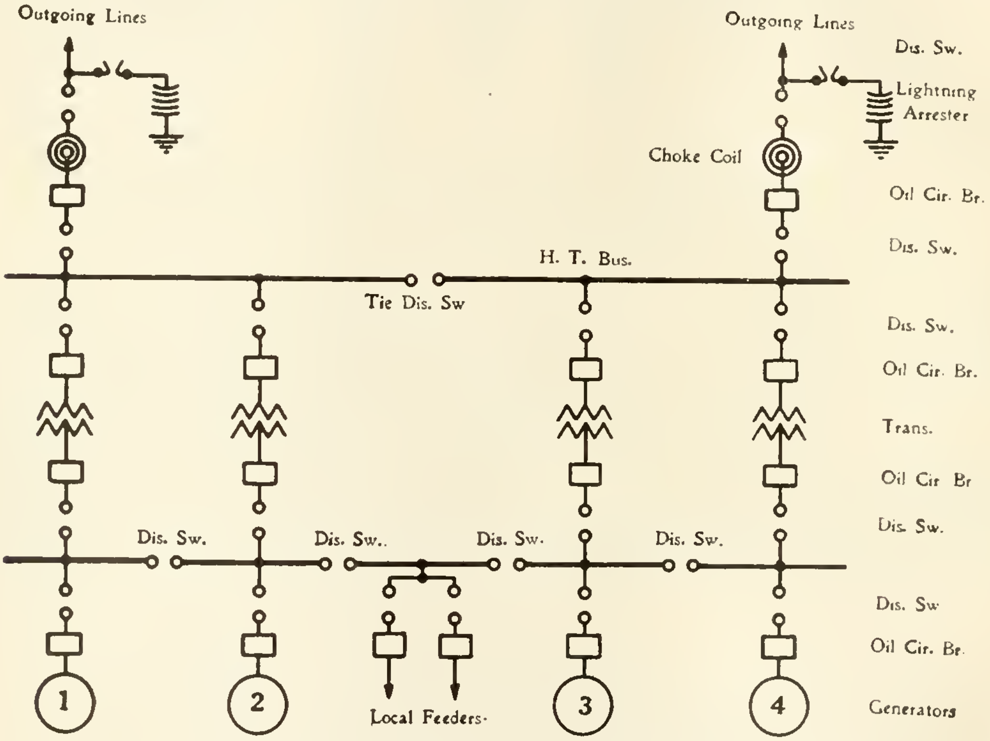

FIG. 9—SINGLE SECTIONALIZED BUS SYSTEM

This system gives great flexibility of operation with minimum cost and is suitable for medium sized plants. Dependence is placed on single circuit breakers. The station may be operated in separate independent halves, local feeders being fed from either half.

In any switchboard installation many refinements in methods and in apparatus for switching and measuring energy may be made, and many safeguards against possible troubles may be installed. Many of these are justified because of their convenience and the time and trouble they save the operator. Each, however, adds to the complication of the equipment, and it should be remembered that usually the simplest scheme which will accomplish the purpose is safest and most reliable, and represents the best engineering.

The disposition to be made of the electrical output materially influences the choice of instruments and meters. It also determines to what extent the service should be guarded against failure. A small station, for example, which is maintained by an industrial plant and whose entire output is used in the manufacturing process, seldom requires more than enough instruments to secure safe operation. An ammeter for each generator circuit and a voltmeter, which may be connected to any generator circuit by means of receptacles and plug, with a second voltmeter for permanent connection to the bus-bars, are commonly used. Non-automatic oil-switches may be used throughout, with enclosed fuses for feeder protection. An occasional shutdown of one or more of the circuits for a few minutes, to replace blown fuses or make quick repairs, would not be seriously

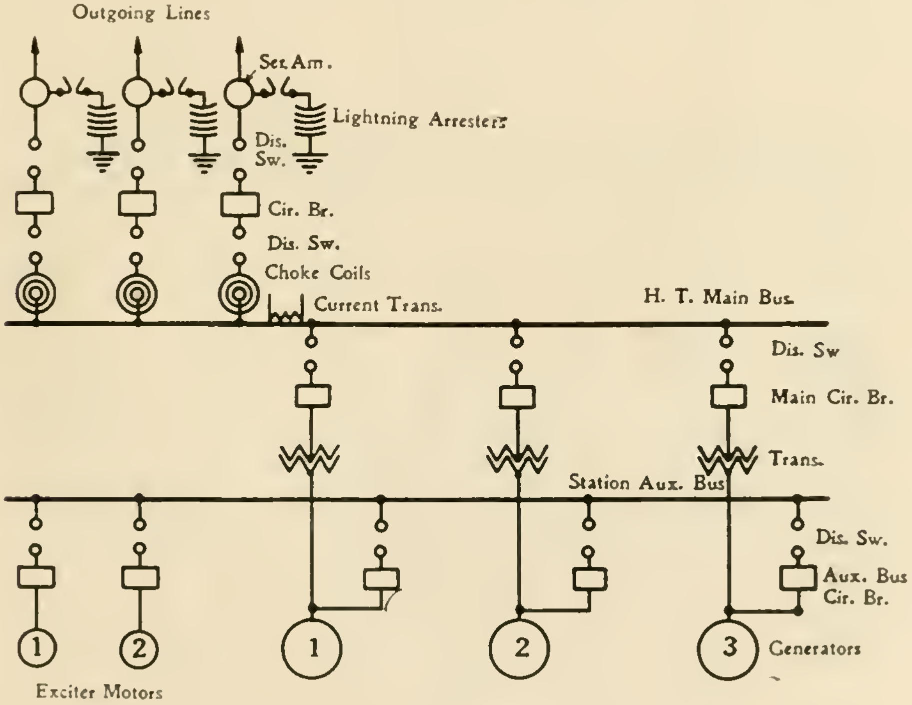

FIG. 10—SINGLE HIGH TENSION BUS SCHEME

The generator and transformer are treated as a unit, and all low tension switching is thereby omitted. The station auxiliaries are fed from any generator or transformer circuit by means of the auxiliary bus. Scheme used by the Homestake Mining Company.

objectionable in this type of plant. One totalizing watthour meter will give a satisfactory check on the station output.

Where the product of the plant is of such a nature that a constant source of power is essential, circuit breakers are usually employed instead of fuses. A double-throw system may be necessary so that the load can be transferred quickly to a clear bus-bar in case of trouble. The manufactured product may be susceptible to injury by over or under speed of the driving motors, thus requiring overvoltage or under voltage trip features on the circuit breakers.

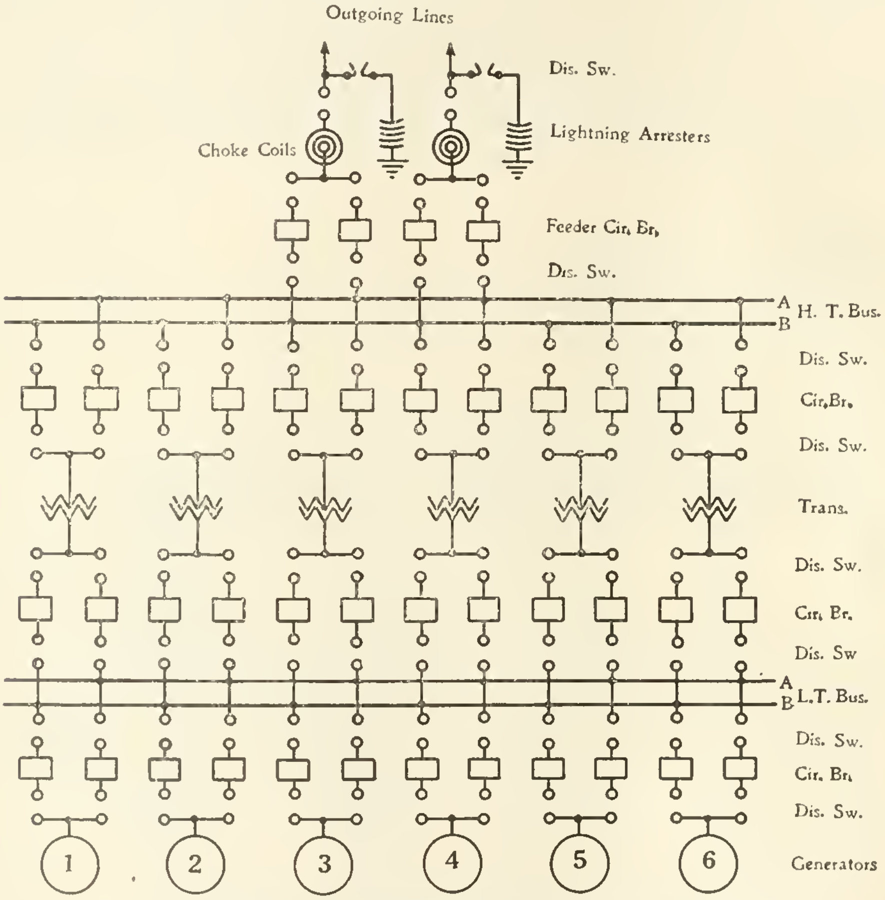

FIG. 11—DOUBLE BUS, DOUBLE CIRCUIT BREAKER SYSTEM THROUGHOUT

This arrangement permits the use of any or all of the generators, without regard to which of the transformers may be in operation. It is particularly suitable where the station output is taken over but two or three transmission lines to the same destination. This is the arrangement used by the United States Reclamation Service in the Salt River Project. Low tension connections similar to those shown are used by the Indiana Steel Company who, however, employ the single circuit breaker scheme for all high tension systems. Similar connections are also used by the Seattle Light & Power Company.

When the output is used to furnish light as a public utility, the service should be continuous and the voltage constant. The better class of apparatus must be used throughout on such installations, a voltage regulator employed and wattmeters installed on the circuits where records are desired.

It is clearly impossible to give definite rules as to what indicating and recording apparatus should be used and what to omit. Each installation usually has certain features requiring arrangements more or less special to itself. One may require a watthour meter for each generator, so that the output of each machine may be checked and so that, on light station loads when but one generator is required, the wattmeter measuring the station output will still be working at maximum accuracy. The daily load curve may indicate that the output is fairly constant over a continuous period. A totalizing wattmeter may then be used to advantage. If the feeders supply different sections of a factory or different factories, or separate communities, a watthour meter should be used for each.

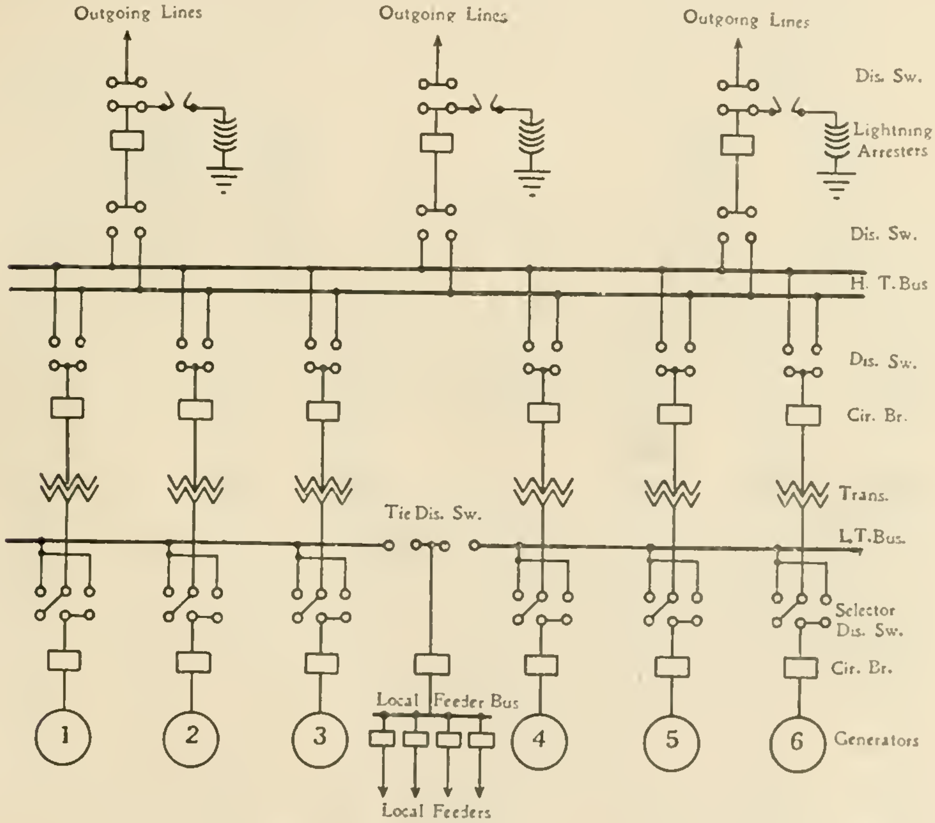

FIG. 12—SINGLE LOW TENSION, DOUBLE HIGH TENSION BUS, SINGLE CIRCUIT BREAKER SCHEME

Low tension disconnecting switches permit the connection of a generator direct to a transformer (with or without connection to bus-bar), connection of generator to bus-bar with transformer dead or connection of transformer to bus-bar with generator dead. This scheme is similar to that used at the Post Falls Station of the Washington Water Power Company, 2 300-66 000 volts. A generator, transformer or feeder must be taken out of service for the examination or repair of its circuit breaker. All apparatus may be in service while load is removed from either section of either bus-bar for repairs or additions.

The class of attendants in charge of the switchboard determines, to a very great degree, how many and what kind and class of instruments should be selected. Instruments which are not used, and which are not kept in calibration, are often worse than none at all, as they only take up valuable space, confuse the operator and complicate the wiring. The more simple the equipment throughout an installation the better the results obtained. It should be the engineer's rule, for stations of this class, not to use apparatus in connection with the switchboard which is not actually necessary to the safe operation of the station. On the other hand, this rule does not hold for the larger stations, whose operation is entrusted to trained engineers, for they usually justify the use of many of the finer in-

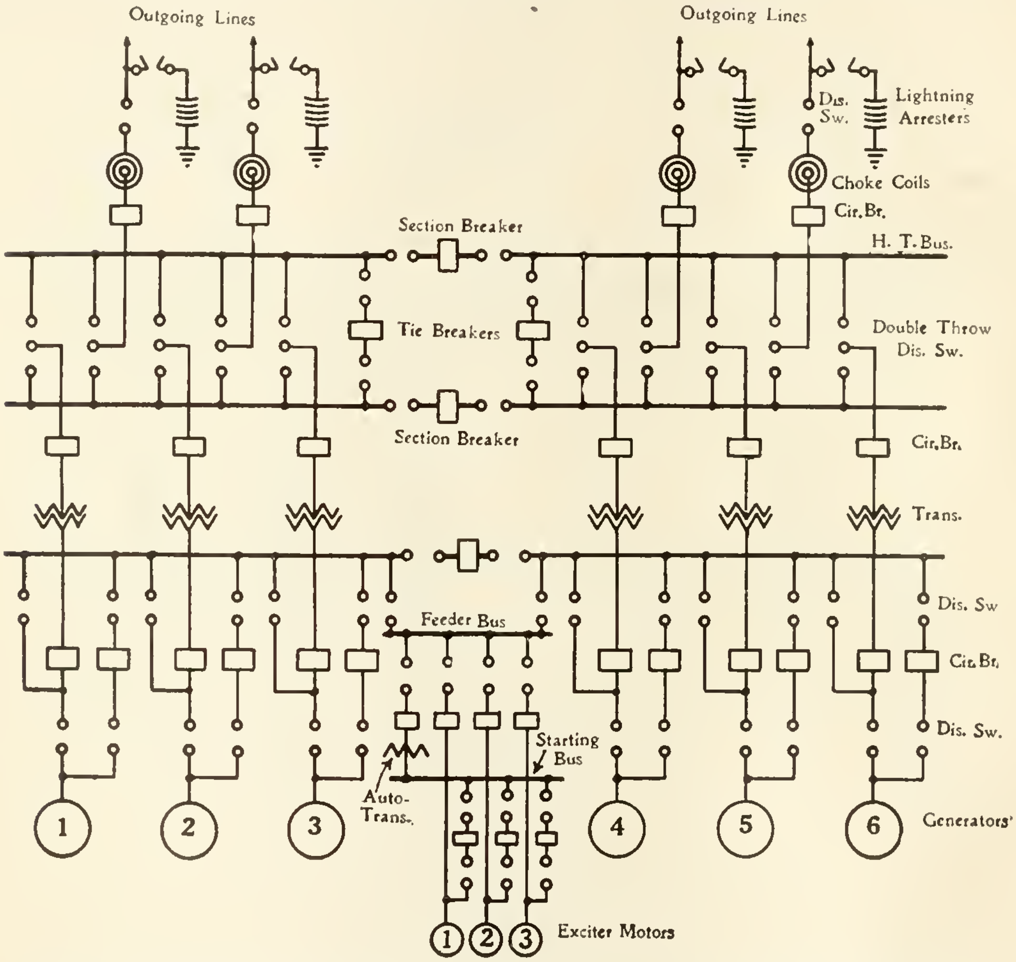

FIG. 13—SINGLE LOW TENSION TRANSFER BUS, DOUBLE HIGH TENSION BUS

With this scheme, used by the Rio Janeiro Tramways Light & Power Company, the station may be operated in four separate parts, if desired, any or all of which may be connected together at will. The double-throw high tension disconnecting switches prevent inter-connecting the high tension busbars except by means of the tie breakers. The low tension connections make it possible to connect a generator directly to its transformer or to any other transformer through the transfer bus.

struments by producing and maintaining, with such an equipment, a highly efficient power station.

As a guide to the selection of a suitable equipment the following panel schedules are presented:

ALTERNATING-CURRENT GENERATOR PANEL

One alternating current ammeter (where phases are likely to be unbalanced an ammeter is often supplied for each phase, or current transformers and ammeter switches provided for connecting the single ammeter to any phase.)
One alternating current voltmeter (or a voltmeter receptacle and plug to connect to station voltmeter).
One direct current ammeter—for alternating-current generator field (optional).
One indicating wattmeter (optional).
One power-factor meter (optional).
One frequency meter (optional).
One ground detector (optional).
One field discharge switch.
One controller for engine or water wheel governor (optional and only supplied when engine governor is controlled at the switchboard in synchronizing).
One rheostat for generator field (usually supplied with generator).
One rheostat for exciter field—required only when generator has its own separate exciter (usually supplied with exciter).
One synchronizing outfit (not required if but one generator is to be installed).
Necessary current and potential transformers.

DISCUSSION

Indicating wattmeters while directly indicating the output of each machine will show what portion of the load is carried by each generator. This cannot be determined by means of the ammeters and voltmeters alone, as they do not take into account the power-factor of the circuit.

Power-factor meters also indicate, but in a different manner, how the generators are dividing the load. In combination with the ammeters and voltmeters they will permit the ready calculation of the load in watts. They also guide the attendant in adjusting the field excitation to obtain the best results.

Voltage readings for the generators are usually taken by means of the "machine" voltmeter, which is usually mounted on a swinging bracket at the end of the board, and the voltmeter receptacles on the individual panels. Most operators require a second voltmeter mounted on the same bracket with the machine voltmeter and connected permanently to the bus-bar. This arrangement permits a simultaneous comparison of the bus-bar and machine voltages when synchronizing.

The synchronizing outfit may consist of synchronizing receptacles with lamps, or with synchroscope, or both. The most popular practice is to place the synchroscope with two synchronizing lamps on a swinging bracket beneath the two voltmeters, where the entire

Field ammeters are considered almost indispensable by most operators, as they assist in properly adjusting the field so that the machine will take its load. All generators are more efficient with the field adjusted to a certain value, as determined by their design. The field ammeters enable the operator to make this adjustment accurately at all times. They indicate the presence of cross-currents between machines, and also assist materially in locating any trouble which may occur at the generator.

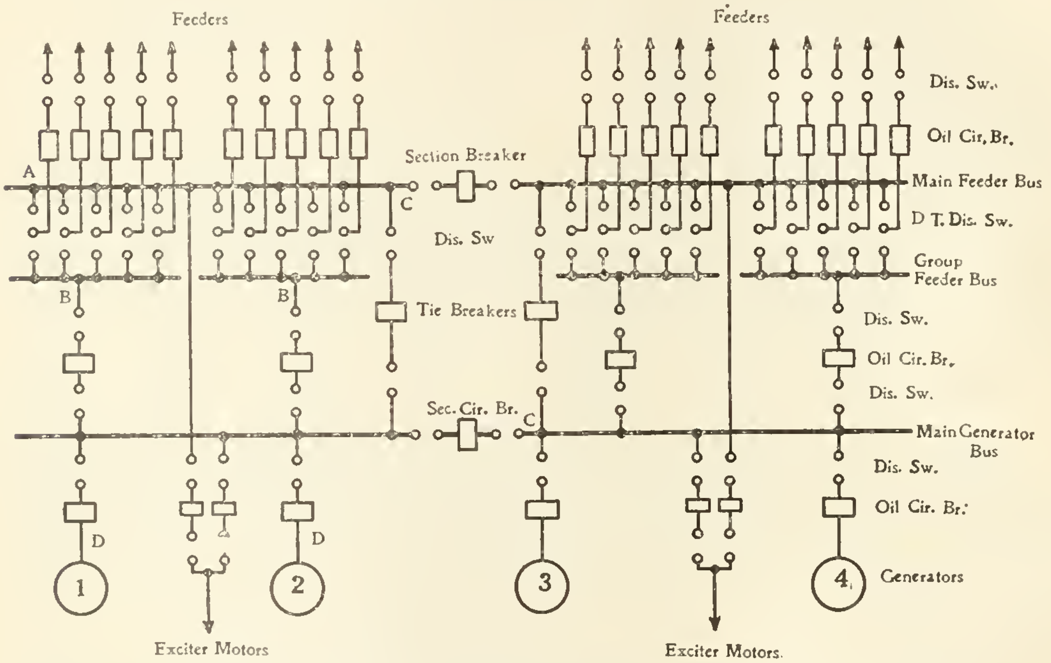

FIG. 14—SECTIONALIZED GENERATOR AND MAIN FEEDER BUS SYSTEM WITH GROUP FEEDER BUS

By this system great flexibility may be obtained for large stations feeding a thickly settled community at generator voltage. The station may be operated in halves or any feeder or group of feeders may be served from either half. Similar connections are used by the Cleveland Electric Illuminating Company.

Frequency meters are an aid in synchronizing, as they indicate the speed of the generator. They are often used as one of the individual panel instruments with large generators, but otherwise but one station frequency meter is supplied. Where there are two or more sets of bus-bars, or several stations feeding into a common transmission line their use is often of vital importance.

Watthour meters are not commonly placed on generator panels. They are usually applied to the feeder circuits, but a load totalizing wattmeter is also often employed when it can be conveniently applied. They are, however, sometimes used to record the output of the individual generators.

Relays are seldom used with generator circuits except to protect against reverse current, which would motor the unit and perhaps injure the prime mover. Sometimes, however, overload relays are used to indicate excessive load by operating a signal. Underload relays may be used in a similar manner.

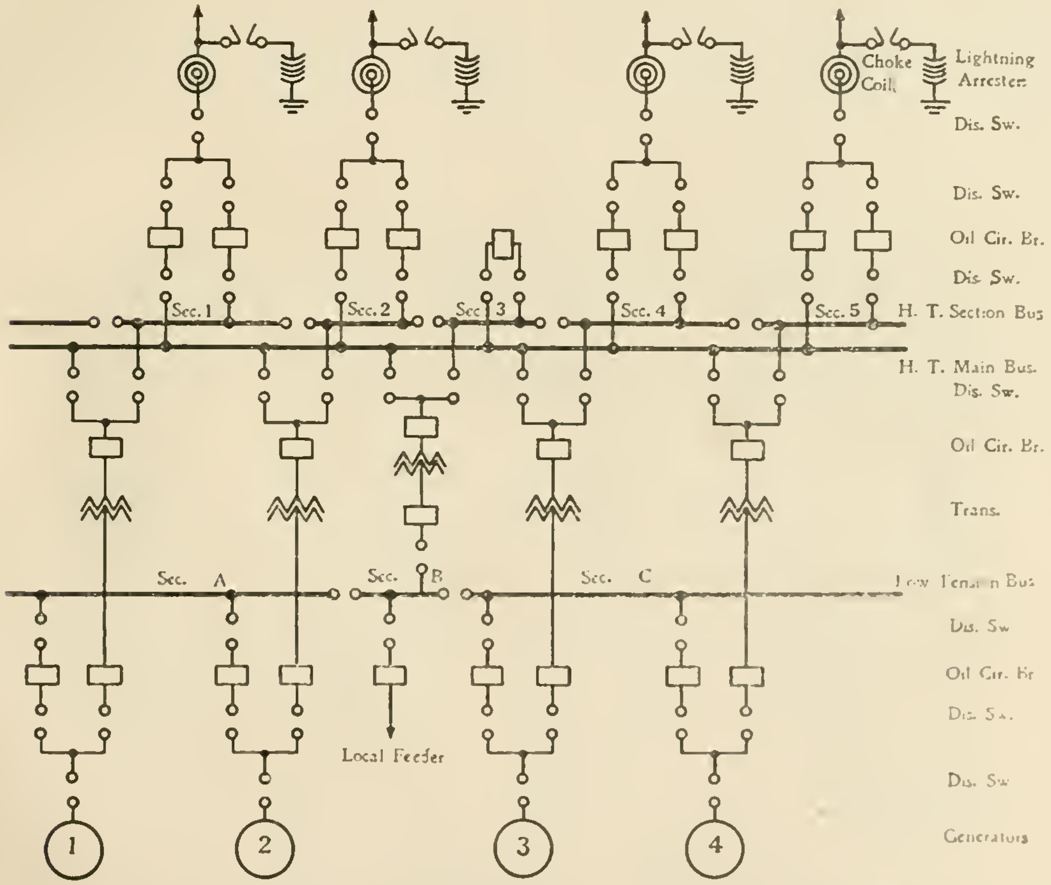

FIG. 15—SINGLE SECTIONALIZED LOW TENSION BUS, WITH TWO HIGH TENSION BUSSES, ONE OF WHICH IS SECTIONALIZED

The station may be operated as four complete units (generator, transformer, and line separate), or any generator may feed any bank of transformer through the low tension bus-bar. The lowering transformer for local or station service permits the low tension bus-bar and circuit breakers to be taken out of service entirely without interfering with the load. This scheme is used by the Washington Power Company, Little Falls Station.

FEEDER PANELS FOR MOTOR OR POWER SERVICE

One alternating-current ammeter (ammeter receptacles or one ammeter per phase may be used if phases are unbalanced).
One indicating watthour meter (optional).
One automatic overload circuit breaker.
One relay (optional).
Necessary current and potential transformers.

DISCUSSION

Unless it is desired to have the circuit breaker trip instantaneously at a certain predetermined overload, an inverse time limit or definite time limit relay should be applied. Many electrically operated circuit breakers, especially of the higher capacities, require some form of relay to render them automatic.

LOAD PANEL

Any or all of the following instruments may be placed on the load panel, and most of them can be obtained in the graphic recording type if desired:—Watthour meter, voltmeter, ammeter, indicating wattmeter, frequency meter, synchroscope, power-factor meter or static ground detector. Sometimes the voltage regulator, when used, is placed on the load panel, especially when there is sufficient space available which would otherwise be vacant.

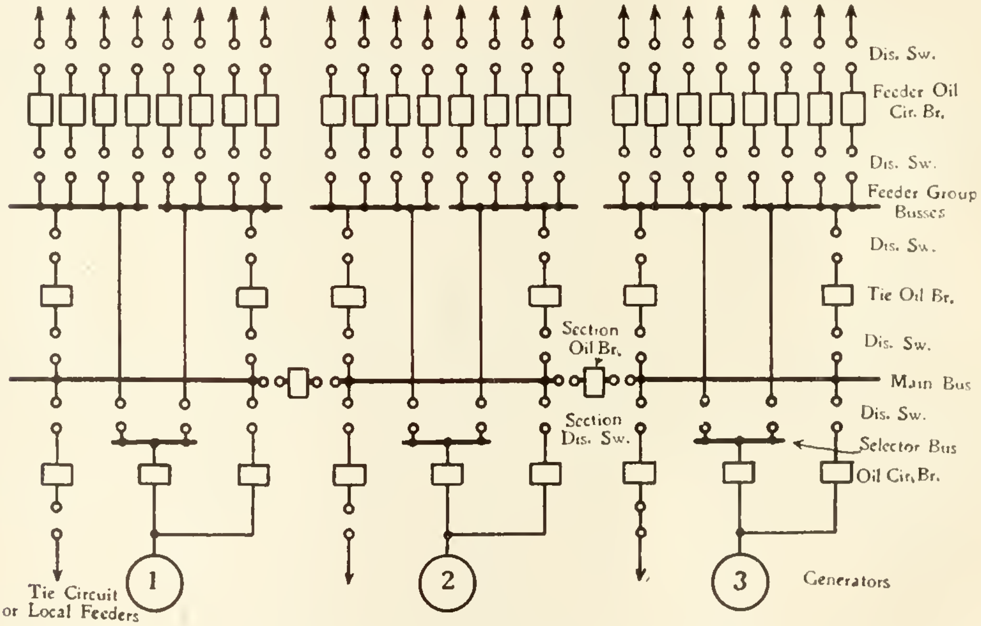

FIG. 16—SINGLE BUS FEEDER GROUP SYSTEM

This arrangement is suitable for stations employing large units, each supplying a number of feeders. Each unit and its group of feeders may be operated independently, or all may be operated from one main bus. This arrangement is used by the Commonwealth Edison Company, Chicago, at its Quarry Street Station.

SYNCHRONOUS MOTOR PANEL

One alternating-current ammeter.
One indicating wattmeter (optional).
One power-factor meter (optional).
One direct-current field ammeter (optional).
One field rheostat (usually supplied with motor).
One field discharge switch.
One synchronizing outfit (not required if motor is self-starting).
One automatic overload oil circuit breaker.
One relay (optional).
Necessary current and potential transformers.

DISCUSSION

But one ammeter will be required for this panel as there should be the same current in each phase. The indicating wattmeter or power-factor meter, as in the case of the generator, will assist the operator to adjust the field properly so that the motor will take its proper load. The field ammeter is of great assistance in making a proper adjustment of the field to meet the desired conditions. Its importance is further increased by the fact that motor guarantees are usually based on a certain definite field current.

The field switch is made double throw for machines which start as induction motors to permit short-circuiting the field during starting. The same machine, however, when equipped with a direct-connected exciter, may be provided with a single-throw field switch as the field is short-circuited across the exciter armature when the field switch is closed.

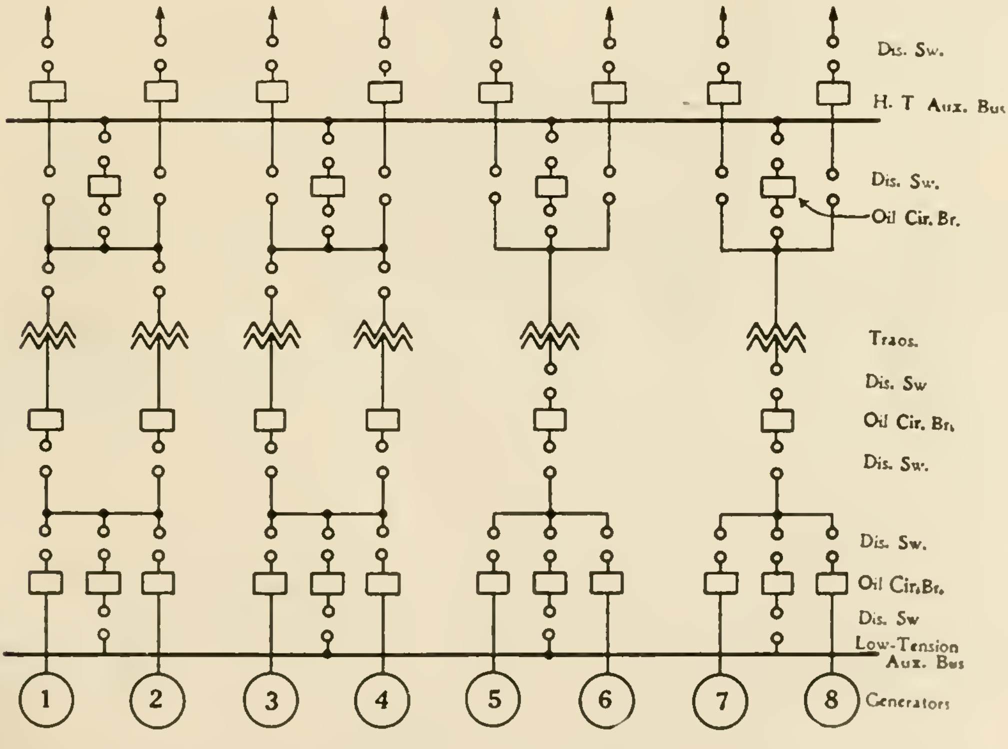

FIG. 17—GENERATOR AND FEEDER GROUP AUXILIARY BUS SYSTEM

By this system all groups may be operated either independently or in parallel. The large transformers may have the capacity of two or more generators. A number of duplicate lines of different characteristics may be taken from the same power station. This is the arrangement used by the Mt. Hood Railway & Power Company.

When the motor is not self-starting the usual single-throw circuit breaker may be used. When it is started from taps on its own power transformers a double-throw circuit breaker, automatic on the running side only, is used. When auto-transformers are employed for starting, a special double-throw auto-starter switch, automatic only on the running side and with provision for disconnecting the auto-transformers from the source of power, is used.

For very large motors, and for motors connected close to large generating stations, three interlocked circuit breakers are usually employed; one automatic, for connecting the machine to the source of power, one for starting, and one for disconnecting the auto-transformers.

LINE PANELS

For Transmission Lines to Sub-stations or Tie Lines to Other Power Stations.

One ammeter per phase (or one ammeter with polyphase switching device).
One indicating wattmeter (optional).
One power-factor meter (optional), or
One wattless component indicator (optional).
One voltmeter, or voltmeter receptacle (optional).
One watthour meter (optional).
One synchronizing outfit (required only for tie line).
One automatic circuit breaker.
One relay (optional).
Necessary current and potential transformers.

DISCUSSION

Three ammeters are usually considered necessary, as they not only give a direct indication of unbalancing of the load, but also of any trouble which may occur on any phase.

Power-factor meters are very commonly used on these panels as an efficient system should operate at high power-factor, and the instruments will indicate those parts of the system which require modifications of their load to better the power-factor, which in turn reduces unnecessary line losses.

Voltmeters may be compensated to read the voltage obtaining at the end of, or at some point along the transmission line. For tie lines the voltmeter is useful in synchronizing with other stations. The voltmeter receptacle may be used instead, to read the potential by means of one of the station voltmeters.

Where power may be taken over the line in either direction the instruments should be double reading and two watthour meters provided, arranged to read power in opposite directions, and so arranged that the mechanism will not reverse.

ALTERNATING-CURRENT ROTARY CONVERTER PANEL

One alternating-current ammeter.
One power-factor meter (optional), or
One wattless component indicator (optional).
One main oil circuit breaker (for high tension side of transformers).
One knife switch, for synchronizing resistance, when used (optional).
One synchronizing outfit (not required when rotary is self-starting).
One relay for circuit-breaker (optional).
One fused switch or automatic oil breaker for starting motor when used.
One set knife switches (for low tension side of transformers when rotary is self-starting. Usually mounted on separate starting panel when rotary is over 500 kw capacity).
Necessary current and potential transformers.

DISCUSSION

Rotary converters are designed to operate most satisfactorily at a certain definite power-factor, usually unity, and it is therefore almost necessary that either a power-factor or wattless component indicator be used. An indicating wattmeter when connected properly, by means of a suitable switching device to its transformers will read true watts with the switch thrown one way and the wattless volt-amperes, when thrown the other way.

Some who favor the use of wattless component indicators contend that with the power-factor indicator in use the sub-station attendent, when starting up, usually adjusts the field rheostat for practically unity power-factor. At no load this means a very small wattless current but if the transformer ratio is right for 600 volts direct-current, this is done by running the voltage up to 625 volts, or higher. When full load is applied under these conditions the wattless current reaches probably 25 percent, while the power-factor meter will indicate little change, probably dropping to 97 percent. On the other hand, the sub-station attendant has his direct-current voltmeter as a guide. The power-factor indicator gives a direct reading of "power-factor" which the attendant knows to be *the* important characteristic in the operation of the rotary. It is important in this connection, however, that the power-factor meter indicate the power-factor of the rotary alone, and not of the combination of rotary and transformer bank. To insure this the meter should be connected to transformers on the secondary leads of the power transformers or, if connected on the primary side the meter should be calibrated to read the correct power-factor at the value at which the rotary should normally operate, and should be provided with a calibration curve to enable correct readings to be made at other points on the scale. The proper choice of switching apparatus for converters depends on the scheme of operation, the size of the rotary, the characteristics of the power supply and the nature of the load. Its combinations are so many that space does not permit of a complete discussion.

DIRECT-CURRENT EXCITER PANEL

One direct-current ammeter.
One voltmeter (or receptacle to connect to main direct-current voltmeter).
One single-pole non-automatic circuit breaker (optional).
One rheostat (usually supplied with exciter).
One three-pole main switch (two-pole if for operating singly or if shunt wound) or sepate single-pole switches.

Two exciters may be controlled from one "double exciter panel" by adding to the above schedule one ammeter, one rheostat, and the necessary main switch.

COMPARATIVE SPACE REQUIRED

The self-contained switchboard (Class *1*) occupies less space than any other. Its floor plan takes the shape of a long, narrow rectangle, however, which sometimes involves more valuable space than the shorter boards of Classes *2* and *3*, whose switching devices, transformers and busses may be mounted at a distance from the panel in a less important and probably more favorable location. Frequently it is found that owing to the disposition of the space available for the switching equipment a board of Class *2* or *3* must be used, although otherwise a Class *1* board would have answered.

Figs. 1, 2 and 3 give an idea of how the same equipment compares in space occupied when designed according to the three classifications given herein. Fig. 3 has little or no advantage over Fig. 2 in space occupied, but has the advantage that the two parts of Fig. 2, that is, the panels and switching devices, must be within the range of mechanical operation by means of bell cranks and connecting rods, while the two parts of Fig. 3 are, comparatively, unlimited as to location.

COMPARATIVE COST

The cost of the self-contained board is usually less than that of any other type. The remote control mechanically-operated board, with switching devices and bus-bars arranged for wall mounting, may be made as cheap, and sometimes even cheaper, as the saving in length of board may neutralize the additional cost of operating mechanism. Assuming the cost of the switch-board shown in Fig. 1 to be 100 percent, the cost of the same equipment in Fig. 2 would be approximately 115 percent, and for Fig. 3 would be 140 percent.

In some cases great saving in main cables can be effected by arrangements possible with Class 2 and 3 boards, which may result in reducing the total price of the installation to the same figure, or even less than if the self-contained switchboard were used.

CORRECTIONS

In the article by Mr. N. W. Storer in the December, 1912, issue, page 1088, the third line from the bottom was omitted as follows: Irregularities in the track without disturbing the mass of the loco.

In the article by Mr. G. W. Roosa in the December, 1912 issue, page 1070, the first sentence in the second paragraph should read: The only force directly opposing the sustaining component of stability is a force accompanying an increase in e.m.f. required or a reduction in e.m.f. supplied.

WITH THE PUBLISHERS.

Two supplements are included with the present issue, one the Title Page and Table of Contents for 1912, and the other The Nine Year Topical Index.

CIRCULATION STATEMENT FOR 1912

The total edition of THE ELECTRIC JOURNAL for the year 1912 was 154 500 copies. Hence the average edition was 12 875 copies per issue.

VOLUME NINE.

Volume Nine, for the year 1912, contains 1 128 reading pages, and with the Topical Index and Table of Contents forms a book of 1 180 pages. Bound copies for 1912 will be available after February 1. Orders may be sent in at any time and will be filled promptly as soon as a supply is received from our bindery. Notwithstanding the increase in size, the old price of $4.00 per volume will be in effect for the present.

Those desiring to have their copies for 1912 bound should send them prepaid at once, along with the Title Page and Nine Year Index. The charge for binding is $1.25 per volume. Missing copies for 1912 are supplied at 25 cents each.

THE NINE YEAR TOPICAL INDEX

The latest index is a 48-page publication and covers all articles which have appeared in the JOURNAL, from February, 1904, to December, 1912, inclusive.

This Topical method of indexing has been of great use to owners of bound volumes, of which over 9 700 volumes have been supplied from the JOURNAL office alone. To locate any desired article in any volume it is only necessary to refer to the latest index which covers all preceding volumes. In addition all articles on allied subjects are given under the same general heading and frequently other valuable articles can be located at the same time. As a time saver this index has made many friends. An author index is also included for those who may recall articles by remembering the writer's name. Copies will be supplied at 25 cents each, prepaid.

SHOP TESTING OF ELECTRICAL APPARATUS.

With this issue is begun the publication of a series of practical articles on "Shop Testing of Electrical Apparatus." The present article and the one to follow are introductory and preliminary. In the succeeding numbers it is planned to present in concise form the best practice in testing as practiced in central stations and in the works of the large manufacturers. Owing to the necessity of securing the material from various authorities, the articles will be more or less of a composite of the ideas of different engineers. In 1904 the JOURNAL published a series of articles on this same general subject. These articles are still frequently referred to by those fortunate enough to have copies. The issues containing these articles are no longer generally available. In the present series it aimed to present the latest practice in testing in such a manner that these articles will be of even more value to our subscribers than the previous series.

The Isolated Plant for December contains a reprint from the JOURNAL for February, 1910, of a part of the article by Mr. John C. Parker, entitled "Industrial Engineering by the Central Station."

EDISON MEDAL AWARDED TO WILLIAM STANLEY.

By the unanimous vote of all of the members of the Edison Medal Committee, the fourth Edison Medal was awarded on December 13, 1912, to William Stanley, electrical engineer and inventor, of Great Barrington, Mass., "for meritorious achievement in invention and development of alternating current systems and apparatus."

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BOOK NOTES.

"Electricity—Its History and Development" — William A. Durgin. 176 pages, illustrated. Published by A. C. McClurg & Company, Chicago. Price, $1.00.

This is a well written little book, outlining in an interesting style the main events in the development of the electrical art. It is written in a popular style and should prove interesting to any who wish to know electrical history.

"Experimental Wireless Stations"—Philip E. Edelman. 224 pages, 81 illustrations. Published by the author, Minneapolis, Minn. Price, $2.00.

This book is intended mainly for experimenters and to provide a standard design for amateur stations to take the place of the many varieties of hit and miss apparatus commonly purchased or constructed by amateurs. Detailed drawings and explanations are given of the apparatus recommended. "How it works and how to make it" have been combined. The majority of the material is apparently the result of the author's own experience.

The Babcock & Wilcox Company have issued a new edition, handsomely illustrated, of their book on The Sterling Water Tube Boiler. Those interested in steam power generation will find much of value and interest in this book on boiler operation in general and especially with reference to this particular type of boiler.

WANTED.

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THE
ELECTRIC JOURNAL

Vol. X FEBRUARY, 1913 No. 2

Limitations in the Design of Turbo-Generators

The article on "High-Speed Turbo-Alternators in this issue of the JOURNAL presents, with Mr. Lamme's usual clearness, the problems which confront the modern turbo-alternator designer. In connection with this article it may be well to bear in mind that not all of the problems connected with the design and use of these large capacity turbo-alternators belong to the electric manufacturers. Both the users of such apparatus and the manufacturers of raw material must accept some of the responsibilities that go with the use of these machines.

For instance, not all of the problems of ventilation belong to the electric designer. Mr. Lamme has indicated some of the difficulties to be overcome in properly ventilating large turbo-alternators, and has pointed out some of the limitations encountered in providing sufficient space within the machine itself to pass the necessary ventilating air. So far as these problems are internal to the machine, they are the electric manufacturer's, but there are other problems, external to the machine, which properly belong to the operators of such machines. Questions such as the location of the necessary air ducts, cleaning or filtering of the air, the method of preventing excessive heating of the generating room and other problems which are involved in the use of such machinery, are obviously external to the machine itself, and must be solved by the user, rather than the builder. These problems vary with different installations and of necessity cannot be taken care of within the machine itself.

Take, for instance, the matter of disposing of the heat that is emitted by large turbo-alternators. The shrinkage in the space required to house large power plants has been remarkable during recent years. The amount of space occupied by extra high-speed turbo-alternators, as compared with the old fashioned low-speed-engine driven alternators, is astonishingly small. If all of the heat due to the losses in the generators, is exhausted into these comparatively small engine rooms, the resulting increase in temperature may often be excessive. Special means for taking the hot air discharge out of the building as well as bringing a suitable supply of cool air into the generator may, therefore, be necessary. This is a consideration that is due entirely to the large amount of power developed in small generator rooms and therefore pertains particularly to the large modern turbo-alternator. But the problem is not necessarily confined to steam turbo-alternators since the same question has often arisen in large hydro-electric stations.

Another problem brought to our attention by the development of large turbo-alternators is the desirability of improvement in the various materials which enter into their construction. When the engineer reaches the limit of skill in the disposition of materials at hand the only method of improvement lies in bettering the qualities of these materials. We are now utilizing steels of a certain strength and elongation, and having a certain permeability and hysteresis losses; with copper of a certain conductivity, and with insulations of a certain resistance to puncture. If we can get steels of higher strength and permeability and lower hysteresis losses; if we can get conductors of lower resistance, and insulations with higher puncture voltages and better heat resisting qualities, we can, thereby, improve the general result when it finally appears as a turbo-alternator.

Thus the responsibility for future improvement is transferred from the electrical designer to the maker of raw materials. The electric designer, of course, remains directly responsible for the skill used in the disposition of the material available but only indirectly responsible for the qualities of the materials.

The main point we wish to make is that not all of the responsibilities involved in the extension of the use of electricity belong to the electrical designer or manufacturer. Ofttimes the users themselves do not appreciate that advances in the art add additional responsibilities upon their shoulders, and that their difficulties are occasionally due to the fact that they have not given proper consideration to the new problems which recent advances have made of importance.

P. M. Lincoln

Portable Sub-stations

The portable sub-station has been in use for many years, but until recently its application has been very limited owing to the rather high cost of the portable sub-stations which were available. The modern portable sub-station, as described by Mr. Kerr in this issue of the JOURNAL, which is of very recent development, is an equipment wonderfully simple, compact and reliable in operation.

As the name implies, this class of sub-station is portable and, therefore, should be of the simplest and most compact arrangement possible. While the first consideration should be an installation that is thoroughly reliable in operation, it is not to be expected that a portable sub-station should have all the refinements and protective devices of the thoroughly modern stationary sub-stations, and this feature should always be considered in comparing the portable with the stationary sub-station.

The use of steel construction throughout, thereby eliminating all inflammable material, together with the recently adopted plan of enclosing only the rotary converter and control equipment, placing the transformer and high tension switching equipment out doors, have very materially reduced the size of car necessary, with a corresponding reduction in the cost of the equipment.

The various conditions or uses to which the portable sub-station can be put are enumerated in the article, but observation and experience prove that these portable sub-stations, when placed in operation, fill the demand in many ways not contemplated when the apparatus was purchased. The added security realized from a converting outfit that can be moved to any part of the system for temporary use, as well as the increased flexibility of the system, make this equipment properly applicable to practically all classes of electric railways. E. P. DILLON.

Selection of Oil Switches

In selecting an oil switch for any particular application, the circuit breaking capacity and the ampere carrying capacity have to be considered as two entirely separate features, inasmuch as there is no definite relation between the requirements in these two respects. The maximum power to be passed into a feeder under normal conditions may be well defined and limited, but in case of a failure of insulation the automatic switch will be expected to isolate the feeder, and the circuit breaking capacity thus required will depend upon the size and type of the generating plant, and to some extent upon that of the remaining connected load. This point, which does not always receive the attention it deserves, is brought out by Mr. C. H. Sanderson in the article on "Switchboards for Alternating-Current Power Stations," in this issue.

A circuit breaker may be considered as having a stated k.v.a. rupturing capacity, that is to say, it is capable of opening a short-circuit on a generating plant of that capacity; this idea, however, must be used with caution as the ability of the circuit breaker to open the circuit depends ultimately upon the magnitude of the current flowing at the time of separation of the contacts. A short-circuited power plant, running with normal excitation, may give a current of 1.5 to 4 times the normal value. However, when suddenly shortcircuited, the initial rush of current may be twenty to fifty times normal value for turbo-generator installations, less than half this for large water wheel plants, and again considerably less for slow-speed engine-type machines; the exact amount will depend upon the characteristics of the generators and whether the normal current is based upon the "maximum" rating or allows for a continuous overload; it will further depend upon the exact point of the voltage wave at which short-circuit takes place, the possible variation being in the ratio of nearly 2 to 1 for various points of the voltage wave. However, the transition from this initial condition to the final steady state is rapid, the current frequently dropping 15 or 20 percent per cycle for the first few cycles. Circuit breakers which are set for immediate opening seldom interrupt the circuit before two cycles have passed (25 cycle apparatus considered) and many types allow the current to pass for several times this number of cycles. If by means of a time limit device, an interval of, say, two seconds be allowed, the first rush of current need hardly be considered as far as the switch is concerned. The rate at which the abnormal initial conditions subside depends upon the rate at which the flux in the generator field takes up its final value, determined by the joint action of armature and excitation currents, which in turn is influenced by the losses in the armature and field structures under short-circuit conditions, the rate being more rapid, the greater these losses are for a given current. Thus in a generator equipped with dampers for single-phase operation a slower settling down to steady conditions is to be expected than in the same machine arranged for a balanced three-phase output; or again an engine-type generator adapted for gas engine drive will be somewhat more sluggish in this respect than one without special features. We thus see how a switch, which may be said to have a breaking capacity corresponding to 10 000 k.v.a when used in a reciprocating engine power plant, may have a considerably reduced k.v.a breaking capacity if installed in a turbo-generator station.

A. B. Field

HIGH SPEED TURBO-ALTERNATORS

THEIR DESIGN AND LIMITATIONS*

B. G. LAMME

ON account of the large capacities, at high speeds, now being obtained in turbo-generator practice, a number of problems are being encountered, the solutions of which are producing more or less radical changes in design and practice. Some of the limitations encountered are in the relatively high temperatures in certain parts, high losses in a relatively small space, the difficulty of ventilation due to the requirement of passing enormous volumes of cooling air through limited or openings or passages, the type of insulation, fire risks, regulation and short-circuit conditions, etc.

THE PROBLEM OF VENTILATION

In the general problem of ventilation, four conditions must be considered, the total loss or heat developed, the surface exposed for dissipating this heat to the air, the quantity of air required to carry away the heat, and the temperature of the cooling air.

In the conduction of heat from the surface into the air, the quantity of heat per unit area which can be dissipated depends upon the difference in temperature maintained between the surface of the body and the air. When the amount of air passed over a surface is sufficient to take up the heat being dissipated, without an undue temperature rise, then a further quantity of air is wasteful. If the air path through a duct is relatively long, then a considerable width of duct may be required in order to get the necessary quantity of air through it. On the other hand, if the air path is short, a narrow duct may be most effective.

In large, high-speed turbo-generators, the problem of ventilation is one of the most difficult ones encountered. The trouble lies principally in the large total loss expended in a very limited space. The difficulties of the problem may be illustrated by the following example:

Assume a 15 000 k.v.a. 25 cycle, 1 500 r.p.m. machine, having a total efficiency of 96.5 percent. This means a loss of 525 kw. A large volume of cooling air is required for carrying away the heat due to this loss. A simple approximate rule for determining the quantity of air required is that an expenditure of one kw in one minute will raise the temperature of 100 cu. ft. of air 18 degrees C. Therefore, a loss of 565 kw would require a supply of ventilating air of approximately 50 000 cu. ft per minute for a rise of the out-going air of 20 degrees above that of the incoming air. Assuming a velocity of 3 000 ft. per minute, this would mean, with a cylindrical ventilating channel, a diameter of 56 in., which is greater than the rotor diameter itself. However, as ordinarily the cooling air would be supplied to both sides of the machine, the ventilating passage need only be half the above section.

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*From paper read before the American Institute of Electrical Engineers, January 10, 1913.

Obviously, such passages are prohibitively large, and much greater air velocities through the machine proper are necessary. Velocities as high as 5 000 to 6 000 ft. per minute are common, while, in some cases, more than 10 000 ft. per minute has been required in certain constricted sections.

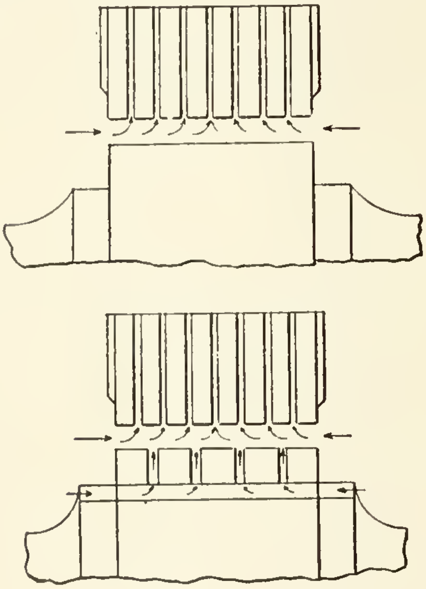


FIG. 1—RADIAL METHOD OF VENTILATION

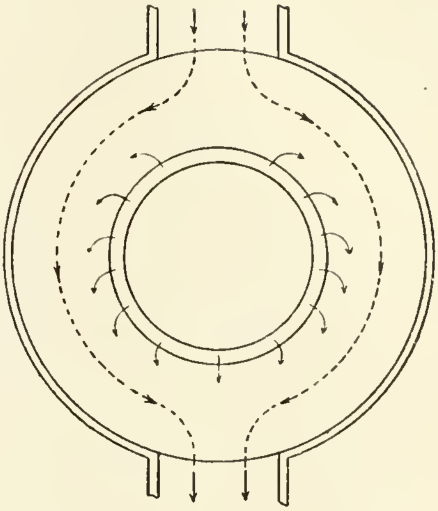


FIG. 2—CIRCUMFERENTIAL METHOD OF VENTILATION

There are several methods of ventilating large turbo-generators. In the radial system, practically all the cooling air passes out radially through ventilating ducts in the stator core. This system can be subdivided into two alternative methods, depending upon whether the air is partly or wholly supplied through passages in the rotor, or through the air-gap alone. These two methods are illustrated in Fig. 1. The straight air-gap arrangement may require a relatively large air-gap, combined with very high velocity of the air, while the other method permits a considerably shorter gap. The straight air-gap method of ventilation is used, to a considerable extent, in 60-cycle two-pole machines. It has proven astonishingly effective in cooling the rotor, and there is usually no great difficulty in forcing through enough air to cool the rotor core.

However, the rotor loss in large turbo-generators is possibly only ten percent of the total loss, and a relatively small proportion of the total ventilating air may suffice to cool it. The cylindrical surface of the rotor core can give off four or five watts per square inch to the cooling air, with a temperature rise of the rotor surface about 35 to 40 degrees above the cooling air.

The real difficulty with the air-gap method of ventilation, is not so much in getting enough air through for cooling the rotor itself, but in the much larger quantity required for the stator. For instance, a one-inch depth of gap with a 50-inch diameter of rotor, means a total section of air path into the gap (counting both ends of rotor) of 314 sq. in. (2.18 sq. ft.). At a velocity of 10 000 ft. per minute, this allows a flow of only 21 800 cu. ft. per minute, which will not take care of a large machine, from the present standpoint of possible capacities with the above diameter of rotor. By additional openings in the rotor core, this might be increased to 30 000 cu. ft. per minute, but even this is still much less than a machine, with a 50-inch diameter of rotor, would require if built for capacities otherwise possible. Therefore, on account of this limitation other means of ventilation have received much consideration. Two other general systems of ventilation, in addition to the gap method, have been used, namely, the circumferential method, and the axial. The former has been developed and applied more extensively in the past, but the latter contains possibilities which are bringing it rapidly to the front.

In the circumferential method of ventilation, air is supplied to one or more points on the outside circumference of the stator, and is forced circumferentially around through the air ducts to suitable outlets, also on the outside surface. Air-gap ventilation is usually combined with this circumferential method, partly to cool the rotor. The general arrangement is indicated in its simplest form with one inlet and one outlet diametrically opposite in Fig. 2. A serious objection to this method of ventilation is found in the limited section of the ventilating path. Assuming, for example, a depth of stator core of 20 inches outside the armature slots and a total of forty ⅜ in. ventilating ducts, or a total effective duct space of 15 inches width, then this gives a total section of ventilating path of 20 × 15 × 2 = 600 sq. in., or 4.16 sq. ft. On account of the relatively great length of the ventilating path, air velocities of more than 6 000 to 7 000 ft. are not desirable or economical, but even with 10 000 ft. velocity, the total quantity of air would be only 41 600 cu. ft. per minute. Furthermore, this method is handicapped in machines with very high-speed rotors, by interference between the radial and the circumferential systems of ventilation, so that the full benefit of either is not obtained. Below a certain rotor velocity, apparently the circumferential action can predominate, and the method is fairly effective up to the permissible air capacity of the stator ducts; but at very high speeds the radial ventilation may very seriously interfere with the other, so much so, that the radial ventilation alone, even with its very restricted gap section, may give as good results as the two methods acting together.

To avoid this interference, various methods have been devised, such as closing part, or all, of the radial ventilating ducts at the air-gap to keep the radial effect from interfering with the other. One arrangement which has been used in Europe to a considerable extent is indicated in Fig. 3. In this, the alternate radial air ducts are closed at the outside surface, while all are closed at the air-gap. The air enters by the open ducts at the back of the machine, flows both circumferentially and toward the gap, and crosses over to the intermediate ducts by axial openings back of the armature teeth, and then along these ducts to the outlet. This scheme is effective in principle, but is uneconomical in the sense that less than the total section of stator ducts is useful, as regards the quantity of air which can be carried. There is usually one large central duct to allow an outlet for the rotor ventilating air. This particular arrange-

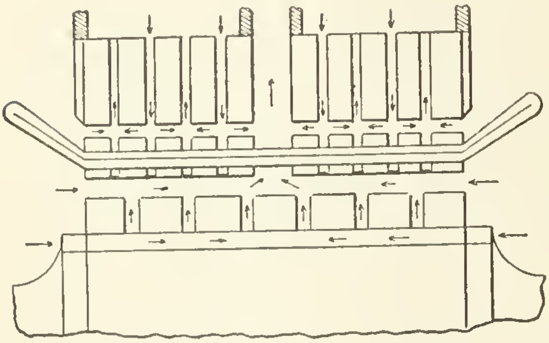


FIG. 3—A VENTILATION SCHEME COMBINING VARIOUS METHODS

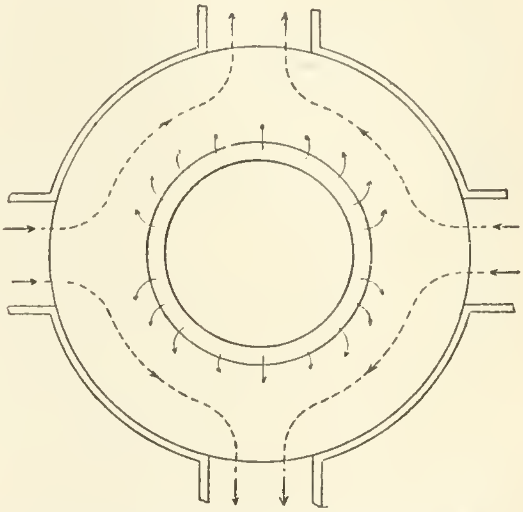


FIG. 4—A MODIFIED FORM OF THE SIMPLE CIRCUMFERENTIAL METHOD OF VENTILATION

ment of the stator also uses axial ventilation in crossing over from one set of ducts to the other, which is an effective arrangement.

A modification of the simple circumferential method of ventilation is to admit air to the back of the stator at two opposite sides of the machine, and deliver it at two outlets at intermediate points on the surface, as shown in Fig. 4. By this means, the cross-section of the ventilating path is doubled and the length is halved. A serious disadvantage in the circumferential ventilation in general is that the ventilating path is relatively long, especially where there is but one inlet and outlet, and therefore the cooling air at the outlet of the channel may be considerably hoter than at the inlet, with consequent points of local higher temperature in the core. In the radial type of ventilation, the coolest air is applied near the seat of the highest losses, namely, at the armature teeth, and immediately back of them, and the air, as it becomes heated, passes over the outer part of the iron which normally has less heat to dissipate. The radial system of cooling is therefore theoretically the most effective, but the difficulty is in applying it, due to the limited air passages available.

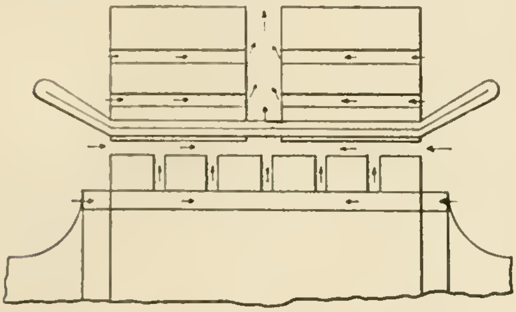


FIG. 5—A METHOD OF VENTILATION USING AXIAL DUCTS

Both the circumferential and the radial methods of cooling are subject to one serious defect, namely, most of the heat generated in the stator iron must be conducted across the laminations to the air ducts. The rate of conduction across the laminations is only 1 to 10 percent as great as along the laminations. Therefore, if the heat could all be conducted along the laminations to the ventilating surfaces, apparently much more effective heat dissipation could be obtained. This has led to the development of the axial system of ventilation, as distinguished from the radial and circumferential. In this method, shown in Fig. 5, a large number of axial holes are provided in the stator core, which may extend uninterruptedly from one side of the core to the other, or they may extend from each side to one or more large central radial channels. The usual numerous radial ducts are omitted, or may be considered as combined in one central channel. The rotor cooling is accomplished by air along the air-gap, and through the rotor core to the large central duct. In very large machines, the problem of supplying the required quantity of air from a suitable blower forms a serious problem. In small capacities it has been the usual practice to attach blowing fans to the rotor. Such fans can supply an amount of air which is limited by the diameter and other dimensions of the fan itself. Assume, for example, that by lengthening the rotor core, or by other modifications in the construction, the capacity of the machine can be doubled, and therefore double the quantity of air is required for cooling. If the limit of the fan design or operation was reached before, obviously some radical change is required with the new capacity of the machine. This condition apparently has been reached in some o fthe later large, high-speed turbo-alternators. One solution lies in the use of separate fans or blowers. There are a number of meritorious features in the use of a separate blower. In the first place, it can be made somewhat more efficient than the high-speed, rotor-driven fans. Again, variable speeds, and therefore different air pressures, can be obtained.

One further condition keeps cropping out in the general problem of ventilation, namely, that of filtering or washing, or otherwise cleaning the ventilating air. With 50 000 to 75 000 cu. ft. of air per minute passing through a large machine, an enormous quantity of foreign matter is carried through with the ventilating air. A deposit of a very small percentage of this in the machine will probably be disastrous. However, the high velocity of the air serves to keep the air passages clear if no oil or moisture is allowed to enter. That a large amount of foreign matter does go through the machine is very soon shown in case a little oil is allowed to get into the ventilating passages.

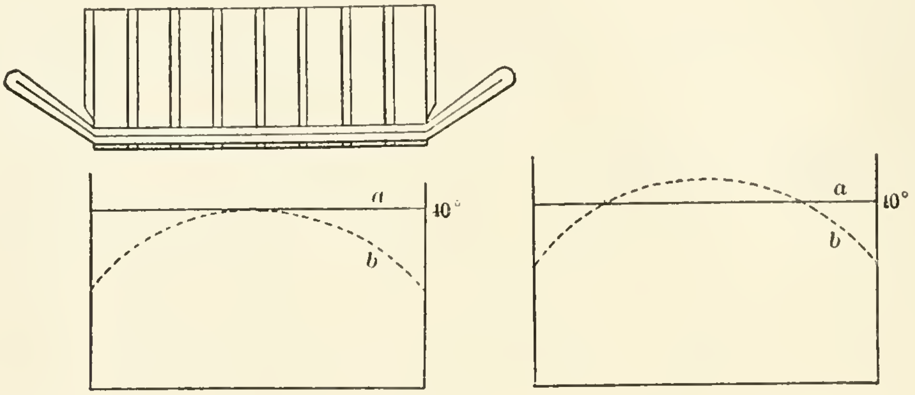
On account of the deposit of dust, etc., in the ventilating passages, it is necessary to clean certain types of machines at intervals, and it is advisable to clean all types occasionally. With some systems of ventilation, where such cleaning is difficult, such as that shown in Fig. 4, provision must be made for cleaning the air before it enters the machine. With the particular construction shown air filters are almost always supplied. In the American types of construction, however, such filters have not yet been used, except in a more or less experimental manner. One modification which is being agitated at present is that of washing, instead of filtering, the air. This serves the double purpose of cleaning and cooling the air, and in very hot weather, when the available capacity of the machine is at its minimum, this cooling effect may mean a reduction of 6 to 10 degrees in the temperature of the machine.

THE TEMPERATURE PROBLEM

In electrical apparatus, it is not the temperature rises, but the ultimate temperatures which are of first importance. The real limitation in ultimate temperature does not lie in the copper and iron, but in the insulating materials. However, as insulating materials in themselves are not usually sources of heat, but receive most of their heat from iron or copper, the real temperature problem, as regards insulation, resolves itself into the consideration of that of the adjacent materials. Therefore, it is one which, for its full analysis, requires a knowledge of the sources and amounts of heat generated, and its conduction and distribution to other parts.

In the armature core, the problem is rather complex. In the copper buried in the armature slots, there are usually three paths along which the heat can flow: First, it may flow from the copper directly through the insulation to the iron. Second, it may flow lengthwise of the copper to the end windings to be dissipated directly into the air. Third, in the case of open-slot machines, one edge of the coil may be exposed to the air in the air-gap, and thus there may be a direct conduction of the heat through the insulation to the air in the air-gap. This latter case, however, only holds for the upper coil in the case of two coils per slot, which is the most common construction. In the bottom coil, the only means of conduction in the buried portion of the coil, are to the adjacent iron or lengthwise to the end windings, or to the adjacent upper coil, which, however, would normally have at least as high temperature as the lower coil. It has usually been considered that, in the buried copper, the greater portion of the heat is conducted directly into the surrounding iron. However, this is only partially true, depending upon many features in the construction and type of apparatus. The heat conductivity of copper is, roughly, about six times that of laminated iron lengthwise of the sheet, and ten to twenty times that across the laminations.

In an armature which is comparatively narrow and which has very open, well ventilated end windings, a relatively small difference in temperature between the copper at the center of the core and that in the end windings, may cause a relatively large flow of heat from the buried copper to the end copper. There even might be conduction from the iron to the copper; for if the copper and iron are at the same temperature at the middle of the core, then as the edges of the core are approached, the copper temperatures will be lower than at the center, and therefore lower than the adjacent iron, on the assumption constant iron temperatures over the full width of the core, as represented in Fig. 6. The solid line *a* in this figure represents the iron temperature at uniformly 40 degrees rise, and the dotted line *b* represents the copper temperatures from the middle of the core to the edges. The effect of this additional heat carried out by the copper would be such as to tend to increase the temperature of the copper at the middle of the core by "banking up" the copper heat. Again, if the temperature of the copper is materially higher than that of the surrounding core, the conditions may be as represented in Fig. 7. In this case there will be heat flow from the copper to the iron at the middle of the core, and from the iron to the copper at the edges.



FIGS 6 AND 7—TEMPERATURE CURVES OF IRON CORE AND COPPER WINDING FOR AN ALTERNATOR WITH A COMPARITIVELY NARROW CORE

This study of the problem leads to certain very curious conditions which are sometimes found in large machines. At no-load, for instance, with practically no copper loss with high iron loss, there may be a very considerable flow of heat from the armature teeth through the insulation into the copper, and thence to the end windings and to the air. In this way the temperature of the armature teeth at no load, and with normal voltage generated, may be reduced considerably by conduction of the iron heat to the copper, while the copper itself may show a considerable temperature rise. When such a machine is loaded, the temperature of the armature teeth may actually increase, due to the prevention of heat conduction into the copper.

In high voltage windings requiring thick insulation, the temperature drop from the copper to the outside may be relatively large. Experience shows that the amount which can be conducted is a function of the quality of the material, the way it is built up, its thickness, and also the pressure upon it.

In the armature iron, the problem of heat conduction is just as complicated as in the armature conductor. The principal sources of heat lie in the armature teeth and in the armature core back of the teeth. As a rule, the loss in the portion of the core immediately back of the teeth is larger than at a greater depth, for the magnetic fluxes generally crowd close to the teeth. The heat from the armature teeth can be dissipated along several paths, lengthwise of the laminations to the end of the tooth and into the air-gap, or along the laminations to the armature core where it can spread out through a path of much greater cross-section. A third path is across the laminations of the teeth, to ventilating ducts. This latter path, however, necessarily must be relatively poor in conductivity, but offsetting this, it is frequently of much greater cross-section and of relatively small length. In passing from plate to plate, the heat must pass through the insulating varnish, or other material used, which is of relatively high heat resistance compared with the iron itself. Nevertheless, in machines with radial ventilation, a very considerable portion of the heat due to the tooth loss is carried transversely through the plates to the air in the ventilating ducts, simply because that is the path of lowest total heat resistance.

The temperature to which the insulation is liable to be subjected, appears to be largely a problem for the designer to determine from his calculations. This is especially the case with very wide armature cores and large, heavily insulated armature coils, such as found in large capacity, high-speed turbo-generators. In such apparatus, the temperatures actually obtained are liable to be materially higher than the usual methods of measurement will indicate. These temperatures are inherent to the conditons of design and cannot be avoided economically in such apparatus as turbo-generators. The limitations in speed, strength of material, etc., force the designer to certain proportions which preclude larger dimensions, or lower inductions in the iron, or lower densities in the copper, or increased ventilation. In such apparatus, therefore, the development apparently lies in the direction of insulations which will stand the higher temperatures which may be obtained. These conditions of higher temperatures in some parts of the machine, than indicated by the usual tests, have been recognized for years by designers and manufacturers of large electric machinery. A rough indication of these temperatures can be obtained by exploring coils or thermo-couples suitably located. However, it is evident that such coils, if located next to the copper, will not give the correct temperature measurement if the flow of heat is from the iron to the copper, and vice versa. It is thus not practicable to determine the actual temperatures of all parts of the insulation, except by measurements of a laboratory nature.

On account of the higher temperatures and the difficulty of making exact measurements, manufacturers very generally have adopted the use of mica as an insulating material on the buried part of the coils. Experience has shown that such material, when properly applied, can safely stand temperatures of at least 125 degrees C.

If exploring coils should show 70 degrees, C, rise, and the permissible ultimate temperature of *fibrous or tape insulation* is assumed as 90 degrees, then obviously, with air at 40 degrees the insulation would be considered as insufficient, except for intermittent service. Plainly, the insulation, for such temperatures, should be of *mica,* for which 125 degrees has been found to be safe. Furthermore, it may be stated that with such mica insulation, a turbo-generator which shows 75 degrees rise by exploring coils has more margin of safety than the ordinary varnished-tape-insulated low-voltage machines of any type, which show 40 degrees rise by thermometer or 50 degrees rise by resistance.

It is thus evident that the temperature problem is a most complex one, in all electrical apparatus, and especially so in turbo-generators. It indicates that no simple temperature test can show all the facts, and that all commercial methods must be considered as approximations. It also shows the absurdity of classifying a piece of apparatus as *good* or *bad,* according to whether it tests possibly one or two degrees below or above a specified thermometer guarantee.

THE INSULATION PROBLEM

The one fundamental condition which must be considerred in the insulation problem, is the durability of the material itself, and this must be viewed from two standpoints—the mechanical, and the electrical. From the mechanical standpoint, the material may have its insulating qualities impaired by the action of mechanical forces which tend to crack, crush or disrupt the material itself, or it may be affected by being permeated by foreign materials or substances, or it may be injured by such overheating as will carbonize it, or render it brittle or otherwise unsuitable. From the electrical standpoint, it may be weakened by deterioration of the quality of the insulating material itself, due to heating, or oxidation or other causes.

The effect of mechanical injury, such as cracking, crushing or overheating, on the insulating qualities, will depend upon many conditions. In some cases, with relatively low voltage, any effective mechanical separation of the parts is sufficient for electrical purposes. Foı higher voltages, continuity of the separating insulating medium is necessary. Experience has shown that, for moderate voltages, temperatures which may injure, or even ruin, the insulating material, from a mechanical standpoint, may not seriously affect its insulating qualities. Many insulating materials of a cellulose nature will still retain good insulating qualities if maintained at temperatures as high as 150 degrees for such long periods that the material itself semi-carbonizes. Under such high temperature conditions, however, it becomes structurally bad—that is, it may become so brittle that it tends to crumble, or powder, or flake off, and thus its value as as insulation is impaired by displacement of the material itself. In low voltages, therefore, it is not a deterioration in the insulating qualities, but rather a mechanical breakdown of the material itself, which is liable to cause trouble. With high voltages, however, the conditions may be quite different, the dielectric strength may be so affected by long continued high temperatures that the insulating quality becomes insufficient.

Certain insulation difficulties have been encountered in large turbo-generators, which, while they would have developed eventually in other large machines, yet became apparent more quickly and prominently in the turbo type, due to the abnormal conditions in its design. The two most prominent difficulties were, first, that of relatively high temperature in the buried copper, already described, and second, the destruction of the insulation by reason of static discharges between the coils and the armature iron.

When the gradual deterioration of the fibrous type of insulation was noted in large turbo-generators, the mica wrapper type of insulation was again taken up and, after considerable experiment, was applied successfully for the outside insulation on the straight parts of the coils. This use of mica overcame the deterioration in the insulating qualities of the outside insulation; but for a while it was considered that a fibrous type of insulation was still effective between turns in those coils where there were two or more turns in series per coil. However, a new condition was encountered in large capacity machines, namely, the insulation between turns, when it became dry and brittle at the higher temperatures, was liable to be injured by the terrific shocks to which the coils were subjected in such machines, in case of a short-circuit across the terminals. The insulation would be cracked or so disturbed that short-circuits would occur later, without apparent cause. These short-circuits on large machines, most often appeared as breakdowns to ground, even with the mica wrapper insulation on the outside of the coil. This led to the practice of insulating the individual turns in each coil, from end to end, with mica tape. After the adoption of this practice, it is noteworthy that the breakdowns to ground practically disappeared, although the outside insulation to ground had not been changed in type or thickness. By means of the mica insulation, the temperature difficulties in general have been entirely overcome, and a durable and non-deteriorating construction has been obtained with the temperatures which appear to be more or less inherent in the large, high-speed turbo-generators.

The second trouble, namely, that due to static discharges between the armature copper and the iron, was also encountered to a certain extent, on some of the earlier machines. It was found that these discharges were apparently "eating" holes, or even grooves, through the outside insulation of the armature coils. This effect was most pronounced at the edges of the air ducts and at the ends of the armature core, where edges were presented by the iron. After a long period, the holes or grooves would become so deep that the insulation was weakened or ruined. This was a very disturbing condition, when it was once fully recognized and appreciated. Various types of machines and windings were examined. It was noted that the action was a function of the voltage of the machine, but was noticeable, in some cases, at relatively low voltages. Where mica wrappers were used with an outside layer of tape, the "eating away" extended only through the outside wrapping in as far as the mica, and no apparent effect at the mica was visible. This naturally led to the conclusion that the most suitable remedy for the trouble was the use of mica insulation, which was also a remedy for the temperature conditions. The mica insulations on the buried part of the coil has now been very generally adopted in this country on high-voltage machines.

ROTOR INSULATION

In most of the early turbo-generators, the rotor winding in the slots was insulated with fibrous material, "fish paper" and "horn" fiber having the preference. One of the difficulties is that the insulation between the winding and the slot is liable to be crushed or cracked by the high centrifugal forces. There is always the possibility of a small amount of movement in the field coils when a machine is being brought up to speed, and this movement, in itself, may eventually damage the insulation if it is at all brittle.

As the capacities and speeds of turbo-generators were increased and the space limitations for the rotor windings became more pronounced, the resulting higher normal temperatures led to the adoption of mica for the insulating material in the slots with either mica or asbestos for the insulation between turns. As the voltage between adjacent turns is always low, a durable separating medium, which will not become crisp or brittle at fairly high temperatures, is needed, rather than an insulation. Asbestos has served for this purpose very effectively, and has some advantages over mica, as the latter must be applied in relatively small pieces in the form of strap or tape, and the individual pieces are more readily displaced or shifted than is the case with asbestos. Some very severe tests have been made in order to determine the possibilities of such rotor insulation. In one case, a turbo rotor thus insulated was run at full speed for over 40 hours, with such a current that the rise by resistance in the rotor copper was about 250 degrees, C. It was the intention to continue this test very much longer, but the conduction of heat from the winding to the core, and thence through the shaft to the bearings, was such that finally the bearings became overheated and gave out. After this test, the winding was carefully dismantled, and no evidence of any injury to the insulation could be discovered.

LOSSES IN TURBO-ALTERNATORS

The total iron and copper losses in a large, high-speed turbo-alternator are in general no higher than in a corresponding capacity low-speed machine. The magnetic flux densities are somewhat lower than in lower speed machines of the same frequency. It is usual to work the armature copper at a lower current density, and therefore at a relatively lower total copper loss. This is somewhat of a handicap in the economical design of the generator, as extra space is thus required for the winding. On account of the compartively large section of armature conductors, the conduction of heat from the buried copper to the end windings is relatively large. The end windings lie more or less across the path of the ventilating air, and there are ample openings between the coils, so that a very considerable part of the ventilating air will pass between the coils of the end windings in such a way as to give the maximum possible ventilation. When it is considerd that the total armature copper loss may be only 20 percent of the total stator loss, it will be seen that an excessive amount of air is not required when the end windings are properly arranged for most effective ventilation.

Much effort has been expended in eliminating or reducing the eddy current losses in the buried copper of large turbo-generators, as well as in other types of large capacity alternators. In some instances, tests have indicated that the local e.m.fs. set up in the armature conductors by the flux through the slot opening is very considerably greater than those due to the flux across the slot. The simplest remedy is to sub-divide the conductors into a number of wires or conductors in parallel, so arranged or connected that the local e.m.fs. oppose and, to a great extent, balance each other. This opposition may be obtained by special arrangement of the conductors in each individual slot, or parallel conductors in the two halves of a complete coil may be connected in opposition to each other. Some of these arrangements do not completely balance the opposing e.m.fs., but they include the resistance of the complete coil in the eddy current circuit, so that the eddy losses are not only very materially reduced, but they are distributed over the entire coil, including the end windings, which condition, in itself, represents a very material improvement.

REGULATION AND SHORT-CIRCUIT CHARACTERISTICS

Alternating-current generators can give, at the instant of short-circuit, a much greater current than that which they will give on continued short-circuit. The real possibilities for trouble in this matter did not develop until the large capacity turbo-generators came into use. In these machines, the armature ampere-turns per pole are so high, that the stresses due to the stray magnetic fields on short-circuit are much greater than the natural rigidity of the end windings will withstand. In this country, the types of armature windings has narrowed down to the open-slot construction, usually with an upper and lower coil per slot, with the end winding arranged in two layers, similar to direct-current armature windings. The end winding is extended at various angles to the axis of the machine from almost parallel up to 90 degrees, as shown in Fig. 8. The principal type is one which extends at some angle between 30 and 60 degrees to the axis. There are several reasons for this—first, it allows a very substantial bracing to be applied to the end windings. Second, the stray fields around the end windings do not, to any extent, cut the adjacent solid parts, such as the end housings, stator and end-plates, etc. An angular position of approximately 45 degrees seems to be a good compromise. Ample suports, as shown in Fig. 9, can be applied for bracing the windings against movement in any direction. The coils are so clamped to the supporting racks, and are braced against each other that the windings will sustain a short-circuit across the terminals, without injury.

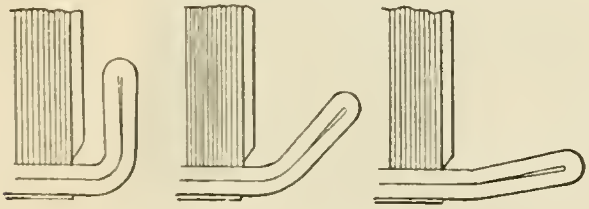


FIG. 8—ARRANGEMENTS OF END WINDINGS

On some recent large turbo-generators, the end windings have been further strengthened by double metal racks between the two layers of windings, so arranged as to key these two layers securely to one another at certain points. Moulded mica troughs are placed around the coils as an extra insulation from the metal racks. By this keying of the two layers to one another, the winding as a whole is stiffened, quite irrespective of any other clamping arrangement.

In order to limit the momentary short-circuit current, the armature reactance is now usually made as large as the conditions of the design will permit. This means high ampere-turns per pole, which in turn means high synchronous reactance, and consequently poor inherent regulation of the machine, especially on inductive loads. This can be illustrated by the following example:

Assume a 500 kw unit of an earlier design, which can give 25 times full-load current on momentary short-circuit. By certain improvements in the design of the armature coils, such as the use of deeper slots, better slots, better subdivision of the copper to eliminate eddy currents, improved ventilation and conduction of heat, etc., the capacity of the machine is assumed to be increased to 10 000 k.v.a., the number of armature turns remaining the same as before. It is evident that when short-circuited, the revised machine will give the same total current as on the former rating, which, however, is only 12.5 times the rated current on the new capacity basis. Obviously, the end winding stresses are no greater than before, although the nominal capacity has been doubled, and if it were possible to brace the end windings satisfactorily with the former rating, the same bracing should be effective on the new rating.

This illustrates, roughly, what is taking place in later designs, although the steps in the change may not be just those mentioned.

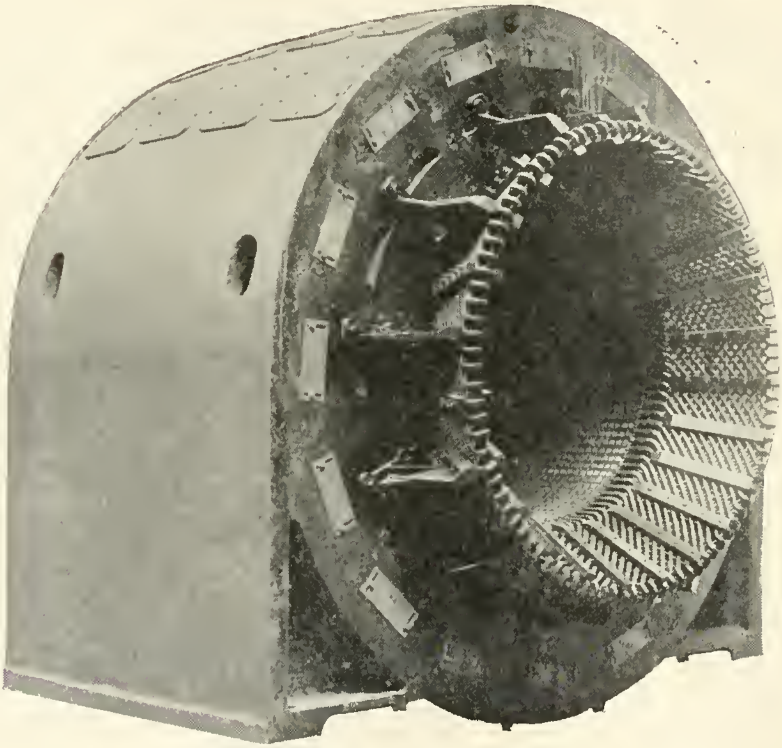


FIG. 9—END VIEW OF STATOR SHOWING ENDS OF COILS AND METHOD OF BRACING

Again, in the above example, it is obvious that, with the new rating, the inherent regulation at full load is the same as at 100 percent overload on the old rating, which means that it is relatively poor. Another way to express this is that the old rating might give 2.5 times full-load current on steady short-circuit, while the new rating gives 1.25 times. This condition of poorer regulation is inherent in the newer practice, but is apparently acceptable to the users of such apparatus.

THE PORTABLE ROTARY CONVERTER SUBSTATION

B. W. KERR

A PERSISTENT study has been made in recent years of ways and means to reduce initial and operating costs on electric railway systems, plans of wide scope having been adopted. Some economies are obtainable only when practiced on a large scale, and would add to the cost of smaller systems. The portable sub-station is not of this class, but can effect great savings both in initial and operating costs on any ordinary system, large or small, that uses high voltage transmission of energy. It was first developed to meet emergencies, but has proved its worth in other directions until it is now recognized as an integral and essential part of the equipment of many operating companies.

Low initial cost of a system, flexibility of operation and continuity of service are three important factors in successful railway operation. It is only within recent years that railway operating men have realized what an important bearing the portable sub-station has on the accomplishment of these three features. Operating conditions on electric railroads vary considerably, but the following are some of the practical applications, taken from experience, in which portable sub-stations have proved their worth. Other and more particular uses will undoubtedly suggest themselves to the experienced operating man.

1—In building a new line or an extension, instead of installing duplicate equipment in each sub-station to insure continuity of service, a single spare unit located in a portable sub-station will provide insurance against interruption for several sub-stations. Taking, for example, a lay-out providing for six sub-stations, this means that instead of installing a spare unit in each sub-station, or a total of twelve rotary converters, seven complete rotary converter units can perform the same duty.

2—In building a new line or an extension, it is often very difficult to determine in advance the most advantageous locations for the sub-stations. A portable station can be tried at several points and under different conditions of load distribution, and thus the question may be settled by actual data instead of by calculations which may not be very accurate.

3—It is difficult to do any complete overhauling in the ordinary sub-station while it is carrying load, or while voltage is on the switchboard. A portable sub-station can be run alongside and the permanent sub-station completely disconnected from the line. The portable station can then carry the load and the overhauling may be done in a minimum of time and at a minimum expense and hazard to life.

4—It is frequently desirable to have the use of power on new construction work when the direct-current feeder system has not yet been installed. A temporary high tension line can be run to the desired point and the sub-station can supply the direct-current.

5—In rebuilding or overhauling a transmission line, a portable sub-station can do good service. The high voltage line can be disconnected just beyond a permanent sub-station and the line fed through the direct-current feeders to the portable, located at the end of the section on which work is being done, where the voltage may be stepped up again by running the converter inverted. A section of the high tension line can thus be entirely disconnected from adjacent sections.

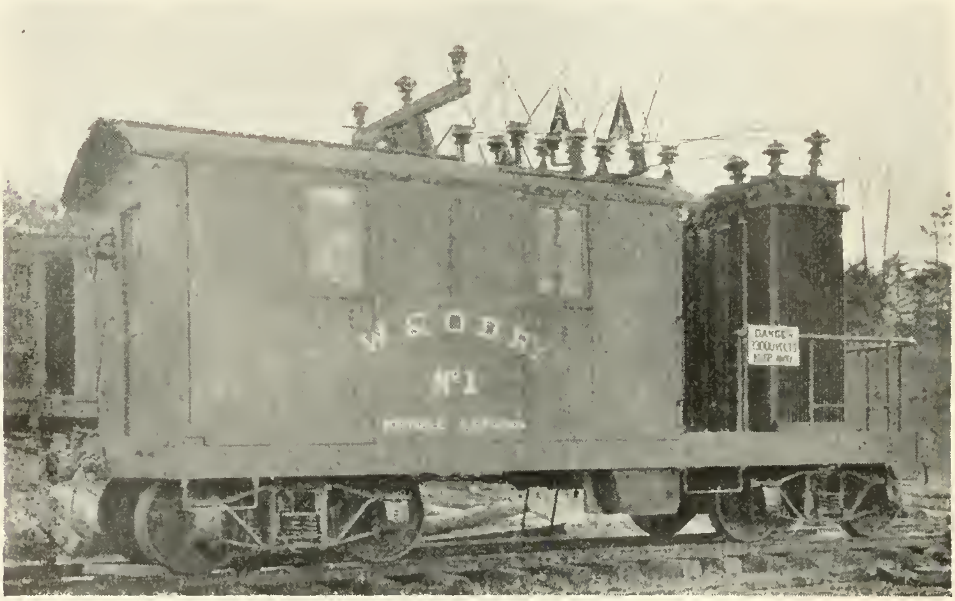


FIG. 1—PORTABLE ROTARY CONVERTER SUB-STATION

One lines of Washington and Old Dominion Railway Company, 33 000 volts primary.

6—For heavy localized and periodical loads such as those due to fairs, ball parks, etc., a portable sub-station can render invaluable service, as it can be moved to points of heavy load without difficulty.

7—Frequently, in soliciting a customer for industrial load from high-tension circuits, it is difficult to estimate the power requirements. With a portable sub-station, this load curve can be determined accurately over as long a period as may be desired, and the customer can then see exactly how much power he will consume.

For any emergency appliance, simplicity, and reliability are essential, and these points must be taken into consideration in designing and specifying a portable sub-station. A few years ago a prevalent idea of a unit of this type was a discarded box-car with an old converter, transformer and switchboard installed therein. These home-made stations served their purpose and proved their worth for emergencies. They were, however, unsafe and the wooden structure introduced a fire risk, which acted against the value of the car in an emergency. Operators realizing the value of this unit requested the manufacturers to supply their needs. At first the home-made designs were followed, with the consequence that their products were but little better than the make shift equipments and, as these designs involved special work, the prices asked were high. Natural development followed. A special study of the unit was made with the idea of decreasing the cost and increasing the reliability and efficiency. The results of this investigation established several points which are now fundamental in the design of an up-to-date portable sub-station.

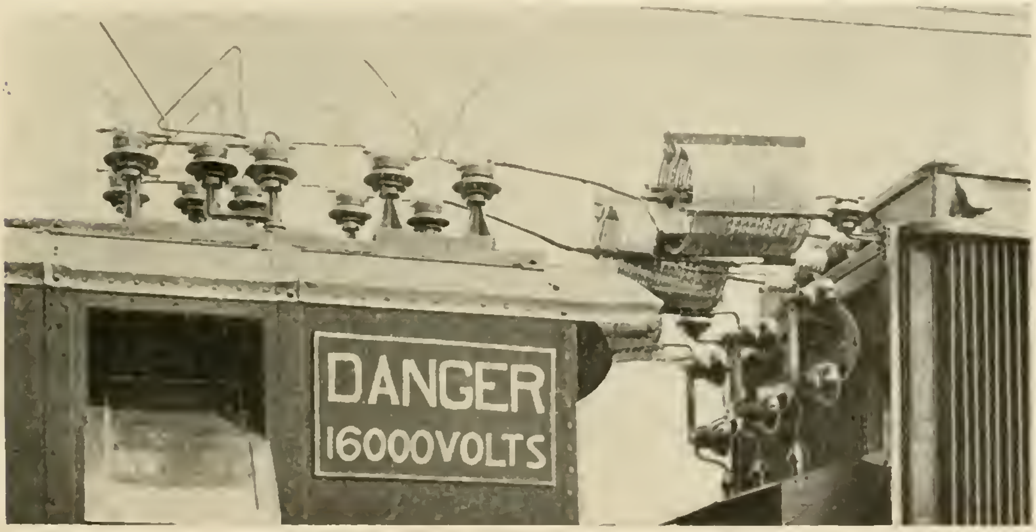


FIG. 2—OUT-DOOR TYPE SWITCHING APPARATUS ON PORTABLE SUB-STATION
Car owned by Scranton and Binghamton Railroad Company.

Inasmuch as the car must be transported to its destination on its own wheels over steam railroads, it is necessary that it should meet all M.C.B requirements and the regulations of the lines over which it passes. The platform height must be standard as must the couplings, draw-bars, air brakes, etc. The clearances must meet the minimum demands of the electric line on which it is to operate and the truck centers must be short for negotiating short radius curves. The under-framing should be specially designed with extra bracing to support the rotary converter. Ventilation is an important point and should be adequately provided for in order to prevent sweating of metal parts and undue heat in summer.

The high tension wiring should be out of reach, preferably located on the roof of the car. This can be accomplished by using an out-door non-automatic horn type switch, horn type fuse, either a horn type or low equivalent lightning arrester and an out-door oil insulated self-cooled transformer. An automatic switch is usually placed on the low tension side of the transformer while the fuse protects the line against trouble in the transformer. This arrangement is illustrated in Fig. 3, and has proved very satisfactory in operation. The transformer should be provided with secondary half-voltage taps for starting the converter, and should be protected by a weather-proof cover with well designed entrance bushings for the high voltage leads.

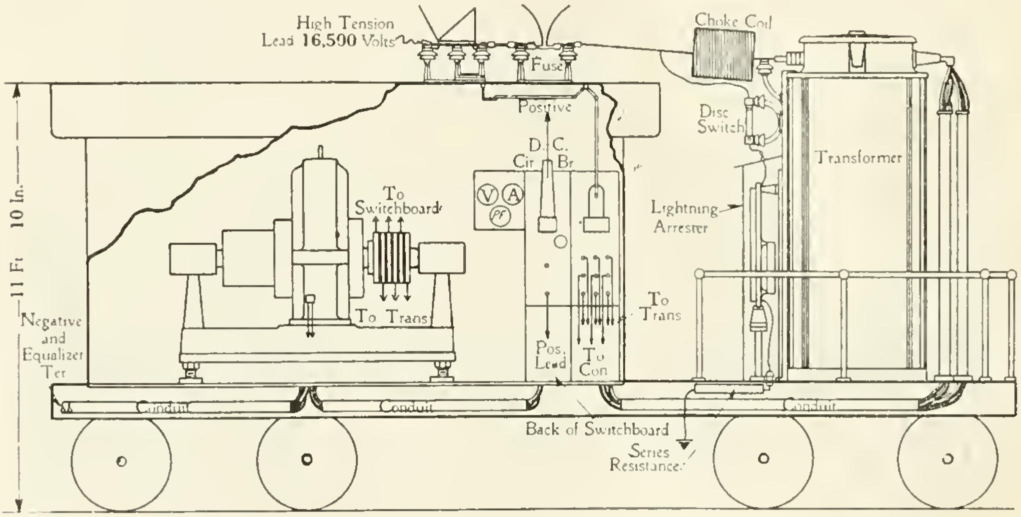


FIG. 3—SCHEMATIC ARRANGEMENT OF APPARATUS IN TYPICAL PORTABLE SUB-STATION

The rotary converter should be started from the alternating current end from half voltage taps on the transformer so as to simplify the wiring. It should be provided with an adjustable base for levelling in case the car is placed on a grade or uneven track. An oscillator and speed limit device will also be of considerable value. If negative and equalizer switches are desired they should be mounted on the frame of the converter, as should the field break up switch.

Simplicity should be the key note in the design of the switchboard and only those instruments specified which are necessary, namely, a power-factor meter and a direct-current ammeter and voltmeter. A single-throw switch and carbon circuit breaker should be supplied in the direct-current circuit and the handles for operating the horn type and rotary switches should be mounted on the board. If a remote control automatic switch is used for the low tension alternating-current leads, it can be mounted beneath the floor of the car and then the cables will not need to be brought up to the switchboard. The running side of the alternating-current switch only should be made automatic. Fig. 3 gives a general scheme of the usual connections, except that the rotary switch is shown as a double-throw switch on the board. The circuit enters at the horn type switches on the roof, passes through the fuse, and choke coils to the primary of the transformer. The secondary leads drop down through conduit and run beneath the floor to the converter switch and then to the converter. The positive lead runs beneath the floor from the converter to the switchboard, and then up and out through the roof while the negative and equalizer leads are brought out at the end of the car. Thus it will be seen that the current passes through a complete circuit of the car and leaves very close to the entrance point.

Lightning protection is afforded either by the horn type arrester or the low equivalent type. In either case a choke coil is necessary but the former is the least complicated. Electric clearances limit the voltage on the primary side to 44 000 volts and the largest station that can be conveniently used on the average railway system is one containing a 500 kilowatt converter.

Consideration of these points has developed a semi-outdoor portable rotary converter sub-station of the general type shown in Figs. 1 and 2. This type of construction realizes the lowest initial cost and maintenance, and secures the most economical and satisfactory operation.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM—(Cont.)

BRAKES FOR ELECTRICALLY OPERATED TRAINS

WALTER V. TURNER and P. H. DONOVAN

FOR electrically operated trains in which all vehicles are equipped with a compressor or have a main reservoir supply line, certain advantageous features may be incorporated in the brake equipment which would otherwise not be possible. Since all the braking power for service can be obtained from a 70-pound brake pipe pressure, it is obvious that the high pressure main reservoir air can be utilized for emergency applications, thus making it unnecessary to increase the brake pipe pressure. To this end, the equipment here described was developed, being perfected to a greater degree than any equipment heretofore designed.

The service and emergency brakes are separated; that is the mechanism and reservoirs controlling the emergency operation are different from those controlling the service operation. About all that is required of the service parts in emergency is to close and open the exhaust ports. Thus two valuable features not realized in any previous brake equipment are attained; first, a large and inexhaustible supply of air for the emergency brake; and, second, a high pressure brake without the necessity of increasing either the brake pipe or main reservoir pressure beyond that now carried by the ordinary brake equipment. From these two features greater safety is secured, due to the increased braking power and very economical operation, since a compressor of about one-half the capacity formerly required may be used.

Another valuable feature of this equipment is that it is so designed that, if desired, cars can be equipped with only the service pneumatic portion. Then, as the service conditions change, the quick action portion can be added. Then, for other conditions, the high-pressure emergency feature can be added; then the electro-pneumatic service feature may be added; and, for still more important operation, the electric quick action or emergency features can be added, and all this accomplished without discarding any parts. This equipment, then, briefly stated, consists of the most improved form of pneumatic service and emergency brake, interlocked with electric control of both service and emergency operations. The important features in detail are:—

Full protection against complete loss of the brake, due to failure of any part of the system; maximum and predetermined flexibility for service operation; certain and uniform action; predetermined and maximum practicable difference between service and emergency braking powers; instantaneous quick action; complete separation of service and emergency features, both electric and pneumatic; full emergency pressure obtainable at will, even after a full service application; automatic emergency when predetermined brake pipe reduction is made after equalization, or when brake pipe pressure is reduced below a predetermined amount due to leakage or other causes; brake cylinder pressure maintained in emergency; improved graduated release features.

The quick action feature is different from previous types of brake apparatus, in that brake pipe air is vented to atmosphere in emergency operation instead of to the brake cylinder.

The quick recharge and graduated release features not only add to the flexibility of control, but also insure an additional factor of safety, because the inherent operation of the apparatus is such that the brakes must be either set or the system recharged ready for prompt application when desired.

Protection against complete loss of brake is insured, since the pneumatic and electric systems are operatively interlocked. While the brakes are being controlled electrically (which is the normal condition), the pneumatic control is held in reserve, without its efficiency in any way being impaired by electrical operation. Consequently, if the electric service control should partially fail from any cause, all the brakes would apply automatically and without the necessity of the motorman even becoming aware of the fact. Therefore, the difference between the electric and pneumatic action is merely with respect to promptness and uniformity on the train as a whole.

The brake application is brought about electrically in the same manner as when applied pneumatically, i.e., by making a brake pipe reduction, in response to which the operation of the mechanism directly controlling the flow of air from the auxiliary reservoir to the brake cylinder takes place in the same manner and produces the same results in either case. The only difference is that in making the pneumatic service application the brake pipe reduction occurs at one point—the brake valve—while, when operating electrically, the service application magnet valves make the brake pipe reduction at the proper rate and simultaneously on each car in the train, which insures a brake application throughout the train in the shortest possible time. A failure of one or more of the application magnets to operate results simply in the brake pipe reduction taking place through the other service magnet valves or through the brake valve.

Certainty and uniformity of service action, combined with protection against undesired operation, due to the inevitable fluctu-

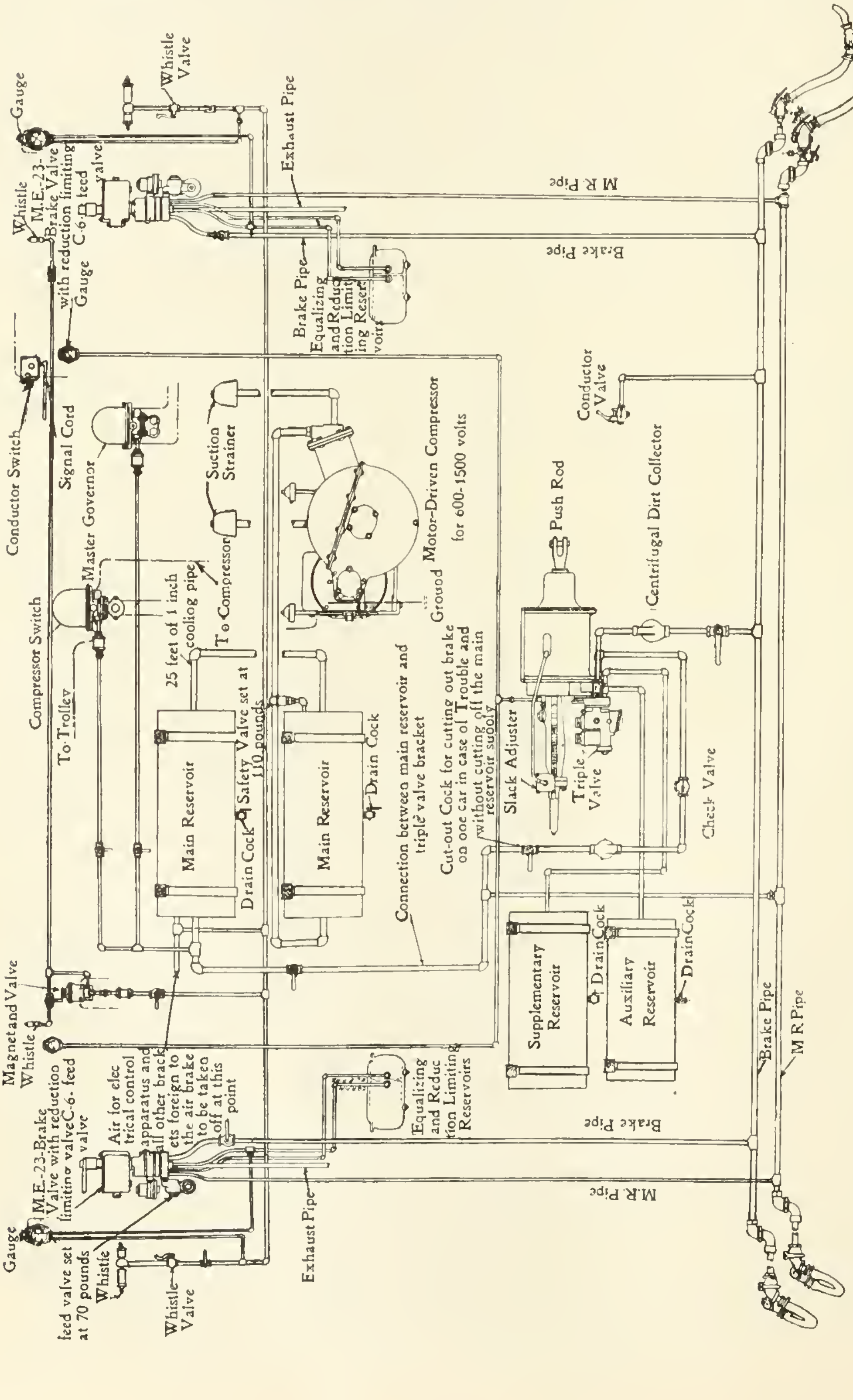

Gauge
Whistle Valve
Exhaust Pipe
Whistle
M.E.-23-Brake Valve with reduction limiting C-6 feed valve
Gauge
M R Pipe
Brake Pipe
Brake Pipe Equalizing and Reducation Limiting Reservoirs
Conductor Switch
Signal Cord
Master Governor
Suction Strainer
Motor-Driven Compressor for 600-1500 volts
Conductor Valve
Push Rod
Centrifugal Dirt Collector
Compressor Switch
To Trolley
25 feet of 1 inch cooling pipe
To Compressor
Ground
Main Reservoir
Drain Cock
Safety Valve set at 110 pounds
Main Reservoir
Drain Cock
Connection between main reservoir and triple valve bracket
Cut-out Cock for cutting out brake on one car in case of Trouble and without cutting off the main reservoir supply
Slack Adjuster
Triple Valve
Check Valve
Supplementary Reservoir
Drain Cock
Auxiliary Reservoir
Drain Cock
Magnet and Valve
Whistle
Air for electrical control apparatus and all other brackets foreign to the air brake to be taken off at this point
Equalizing and Reduction Limiting Reservoirs
Brake Pipe
M R Pipe
M.E.-23-Brake Valve with reduction limiting valve C-6- feed valve
Gauge
feed valve set at 70 pounds
Whistle
Whistle Valve
Exhaust Pipe
Brake Pipe
M.R. Pipe

FIG. 8—PIPING DIAGRAM FOR ELECTRO-PNEUMATIC BRAKE SYSTEM

ations of the brake pipe pressure or small brake pipe reductions, is provided for in the design of the valve, which insures that the equalizing piston will move so as to close the feed groove on the slightest brake pipe reduction, and then the necessary and proper differential must be built up to move the parts to service position, as the brake pipe reduction is continued.

The maximum difference between service and emergency braking powers is possible, since the maximum cylinder pressure in service is determined by the equalization of the auxiliary reservoir and brake cylinder, whereas the emergency brake cylinder pressure is determined by the pressure in the main reservoir, thus giving the effect of a high-speed brake with low brake pipe pressure.

Instantaneous quick action is obtained whether originating at the brake valve or at any point in the train, as the emergency action is subject to the movement of the emergency switch on each car, as well as of the brake valve. The same protection exists for emergency as for service application, i.e., if for any reason the electric emergency feature of the equipment becomes inoperative, pneumatic emergency operation occurs automatically.

The complete separation of the service and emergency functions permits flexibility for service applications without impairing the emergency features of the equipment, and eliminates the possibility of undesired quick action.

GENERAL PNEUMATIC AND ELECTRICAL FEATURES

The piping diagram of the equipment is shown in Fig. 8, consisting of the usual combination of auxiliary reservoir, triple valve and brake cylinder, with the addition of a supplementary reservoir. The functions of the *auxiliary reservoir* and brake cylinder are similar to those of the ordinary quick-action automatic brake. The *supplementary reservoir* assists in obtaining graduated release and the quick recharge of the brake.

Electrically, the equipment comprises *application* and *release magnets*, with their attached valves, controlling the electric service application and release of the brakes, as shown in Fig. 9. In addition to these, there is the *emergency application magnet*, with its valve, controlling the operation of the emergency parts of the triple valve. The operating valve for this equipment, which is composed of two distinct parts, one electric and the other pneumatic, is shown in Fig. 10. The electrical features are placed above the pneumatic and consist of, a rotary drum having four contacts at-

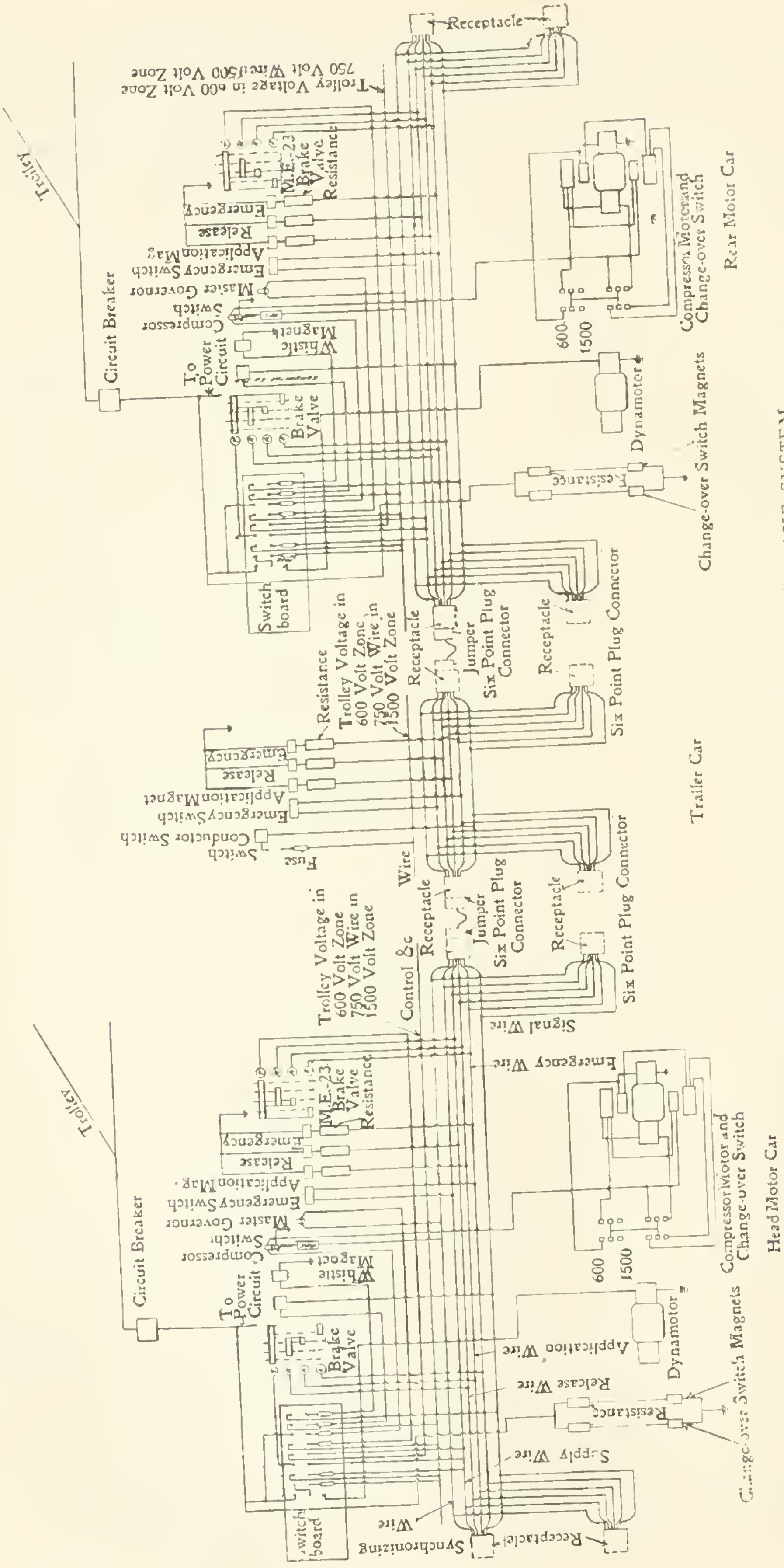


FIG. 9—WIRING DIAGRAM FOR ELECTRO-PNEUMATIC BRAKE SYSTEM.

tached to the same shaft as the rotary valve, and corresponding contact fingers on the body of the valve. The upper finger is connected to the trolley, the second to the release magnet line, the third to the application magnet line, and the lower one to the emergency magnet line.

This type of brake valve has not only the electric control features, but the pneumatic features are developed to a high degree. The pneumatic improvements over the ordinary automatic brake valve are—the limiting of the service brake pipe reduction to a predetermined value by means of a reduction limiting valve; the prevention of overcharge of the equalizing reservoir, obtain by the use of a collapsible equalizing discharge piston; the quick response of brake pipe reduction obtained by the combination of direct and equalizing piston exhaust ports.

The valve has six positions, viz., *release, holding, handle off, lap, service* and *emergency*. The position of the handle of the brake valve is identical for electric and pneumatic service. With the electric features operative, the service magnet valves reduce the brake pipe pressure on each individual car at the desired rate, but if the electric control is inoperative, the pneumatic control will operate and the brake pipe pressure, which controls the operation of the brakes, will be reduced by means of the brake valve. The brake pipe reduction is limited to a predetermined amount, the same as in electric service. If, for any reason, any of the service application magnets in the train are inoperative (thus causing the brake pipe reduction made by the magnet valves to be less rapid than the reduction of the equalizing reservoir), through the preliminary exhaust port of the brake valve the equalizing piston will lift, open the equalizing discharge valve and bring the rate of reduction up to the required point. This feature also warns the motorman of any inoperative service application magnets.

REDUCTION LIMITING FEATURE

The reduction limiting valve, as it is called, is composed of a piston and slide valve, the back of the piston and the slide valve chamber always being connected to the equalizing reservoir, and the face always connected to the reduction limiting reservoir. Normally, the limiting reservoir is connected to the atmosphere, but in service position, while the pressure in the equalizing reservoir is being reduced through the preliminary exhaust port, the reduction limiting reservoir is being charged. When these pressures are nearly equal, the piston and slide valve will move and cut off communication between the preliminary exhaust port and the atmosphere, and since the equalizing reservoir and direct exhaust ports pass through this slide valve cavity to the atmosphere, no further reduction can occur through this source; consequently, when the brake pipe pressure has been reduced to the equalizing reservoir pressure, the equalizing discharge valve will seat, thus limiting the brake pipe reduction. No further reduction can now be made unless the brake valve handle is moved to emergency position. The size of the preliminary exhaust and that of the limiting reservoir charging ports are such that the equalizing and limiting reservoir pressures will be equal at about 50 pounds.

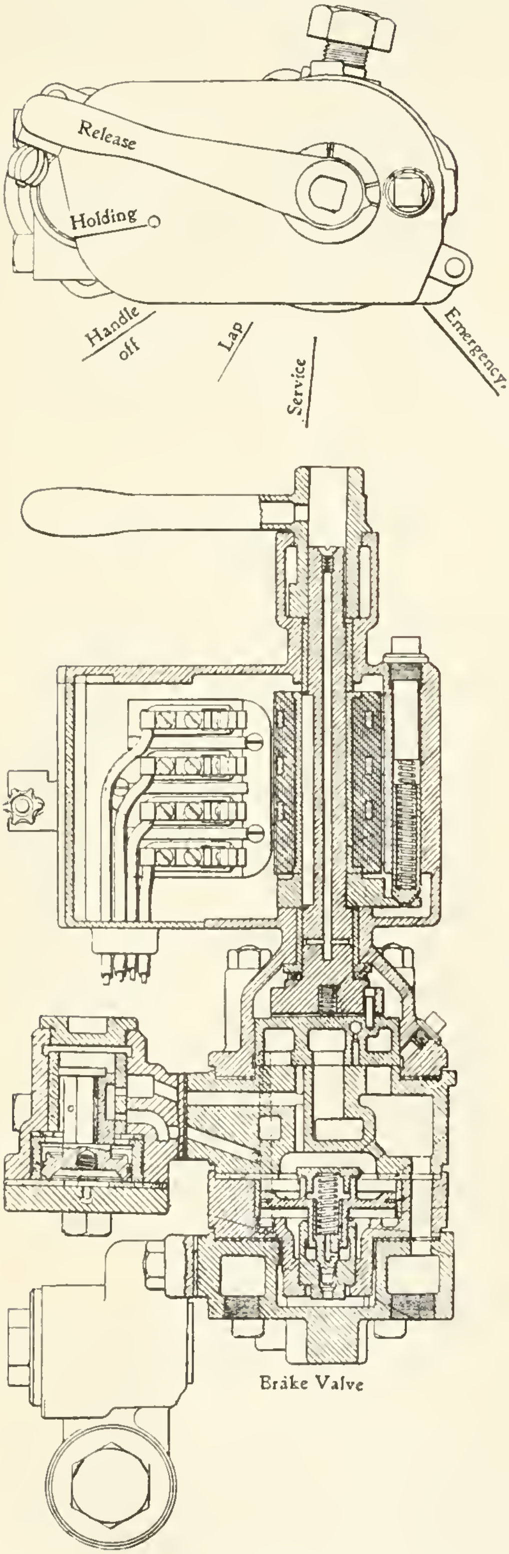


FIG. 10—OPERATING VALVE

NON-OVERCHARGE OF EQUALIZING RESERVOIR

The improved design of equalizing discharge valve piston (collapsible type) prevents the overcharge of the equalizing reservoir. Since the equalizing reservoir pressure is on the top of the equalizing piston, and the brake-pipe pressure underneath, if the equalizing reservoir charges faster than the brake pipe a differential will be built up on the upper side of this piston, which will then collapse, allowing pressure in the equalizing reservoir to equalize into the brake pipe through grooves in the piston bush. The spring in this piston will yield with a differential of about two pounds.

DIRECT EXHAUST FEATURE

In the service position there is a direct exhaust port leading from the brake pipe to the atmosphere. This insures an immediate reduction of brake pipe pressure, and hence application of the brakes.

In the release position of the brake valve, the brake pipe charging port and the equalizing reservoir charging port are open, thus charging the brake pipe and equalizing reservoir to feed-valve pressure. The reduction limiting reservoir port and the brake cylinder port are open to the atmosphere. In this position of the brake valve there is no electrical connection made; therefore, the release magnet valve is held open and the emergency and service magnet valves are held closed by their respective springs.

In the holding position all port connections are the same as in release, except that the brake cylinder port is closed, thus holding the brakes on.

The brake pipe charging port being open, permits the recharge of the brake pipe and the release of all the brakes in the train but on the head car. Thus the brake on this leading car may be retained or, if desired, graduated off by moving the brake-valve handle between release and holding positions. As in release, there are no electrical connections made in this position.

In the service position the preliminary exhaust port is open, thus reducing the equalizing reservoir pressure by way of the limiting slide valve exhaust cavity. The reduction limiting reservoir charging port is open, thus charging this reservoir as the equalizing reservoir is being reduced. The equalizing discharge port is open, as is also the direct exhaust port. In this position of the brake valve the release magnet line remains connected to the supply, and, in addition, the service magnet line is connected, and thus the release and service magnets are energized and the release magnet valve is held closed and the service magnet open.

In the lap position all ports are closed except the equalizing discharge valve ports; the necessity for this being open is evident, since the brake pipe exhaust from the equalizing discharge valve must remain open until the brake-pipe pressure has been drawn down equal to the reduction in the equalizing reservoir pressure.

In the emergency position the brake pipe is connected to the atmosphere through a large port, and the emergency magnet line is connected to the supply, thus energizing the emergency magnet and opening the emergency magnet valve and admitting main reservoir air to the brake cylinder.

(To be continued.)

AESTHETICS IN STREET LIGHTING

GEORGE W. ROOSA

WHEN the wave of general improvement of street lighting conditions began to sweep across the country, civic leagues, merchants' clubs, and the public in general became interested in the decorative unit, sacrificing considerable in the way of financial investment, and paying little attention to illuminating engineering requirements. Instances are on record indicating the most radical change in street lighting conditions. Many cities have changed from the old arrangement with an enclosed arc lamp at each street corner to a more uniform lighting method by locating a number of smaller units in each block on both sides of the street, giving greatly increased illumination. Villages of less than three thousand population, formerly unlighted, are now decorated with ornamental units representing considerable financial outlay for underground service, etc. Apparently little thought has been given, until recently, to the financial side of this question, nor to the engineering features. So it is correct and proper that there be a more thorough study of this subject. Interested lighting committees are calling on experts for advice. They are beginning to realize that improved street lighting means a combination of proper illumination and ornamentation.

Fundamentally, artificial illumination is for protection. Plenty of light is a great aid to the policing of our cities. To many motorists, good illumination is more important than good roads, some even preferring poor streets with good light to well-paved streets poorly lighted, the element of chance being less and the danger of collision being greatly lessened. The pedestrian almost always selects for safety the brightly illuminated streets.

By considering more and more the advantage of economic and aesthetic qualities, we have wisely gone farther than the mere providing of protection and safety, and so have broadened the usefulness of good illuminants. As an advertisement, as an incentive to civic pride and as an ornamental improvement, illumination has received considerable attention. Realizing that good lighting pays in dollars and cents, merchants' associations and prominent individuals have become interested and enthusiastic. Extensive changes in illumination are planned to conform with the architectural surroundings, the aesthetic features predominating. Thus a wholesome and healthy market has been created for suitable exterior units. The demand has come into existence so rapidly that illuminating engineers, architects, designers and electrical experts have found it difficult to cope with the situation. Although a variety of conditions are to be met, a few features are in common essential in a well-designed installation.

FEATURES MOST ESSENTIAL IN GOOD STREET LIGHTING

Comfortable vision is a most important element to be considered. The glare produced by units of high intensity placed slightly above the line of vision is very distressing to the pedestrian, and is frequently very annoying to automobile drivers. Light sources should be properly placed; as in nature, light rays should fall from a high angle and spread light on the area to be illuminated. We quote from the "Primer of Illumination," published by the Illuminating Engineering Society: "Judge the light you are getting by the way it helps you to see. Do not think because a lamp looks glaring and brilliant that it is giving you good light. It may be merely giving you too much light in the wrong place."

The cost of a system is an important item for consideration: not only the initial cost, but the operating cost. Until recently not enough study had been given to this point, with the result that some installations which were intended as ornamental improvements have been badly neglected on account of excessive maintenance cost, and are becoming eye-sores. The advertising value of an installation is of importance. In fact, most "White Ways," installed during the last two years, have been prompted by the self-evident advertising features of well-lighted business districts in other cities. A thorough discussion of the advertising qualities of improved lighting conditions will not be given here, but it should be realized that the advertisement will be in proportion to the interest displayed. Lack of interest, resulting in dirty and broken globes, unrepaired fixtures, part of the lights out and general dillapidated appearance is an advertisement speaking loudly in the wrong direction.

With the popular demand for civic improvements increasing at this time, and with the advantages of artificial illumination becoming so widely appreciated, we find a prominent expression of the importance of aesthetic qualities in the selection of ornamental lighting units for business districts, residential streets, parks, boulevards and in even the outlying and least conspicuous places. Merely to obtain decoration, in conjunction with advertisement, at the sacrifice of more important items is a common fault. We quote again from the "Primer of Illumination:" "Prettiness in a fixture is well enough; but let the fixture be serviceable first; then it may be also as pretty as you wish. But don't buy prettiness if it makes war on good sense." Aesthetic qualities have a value the estimation of which is at the judgment of the parties interested. It is an interesting fact that decorative value or "prettiness" is a matter of taste seeming often to be most variant.

Modern street lighting considered as a territorial question may be divided into three classes, which also show distinct characteristics when other phases, such as the division of costs, the quantity of light and the type of unit, are studied. These classes include the lighting of business districts, residential sections and boulevards, parks and suburban districts. Proper illumination for each requires protection from crime, protection for high speed vehicle traffic, provision for comfortable vision, low initial cost, low maintenance cost, appreciable advertising qualities and decided increase in decorative value, the first two requirements being usually considered as one. It is interesting to note, as indicated in general in Table I, the relative value of aesthetic qualities, an absolute determination of which is impossible.

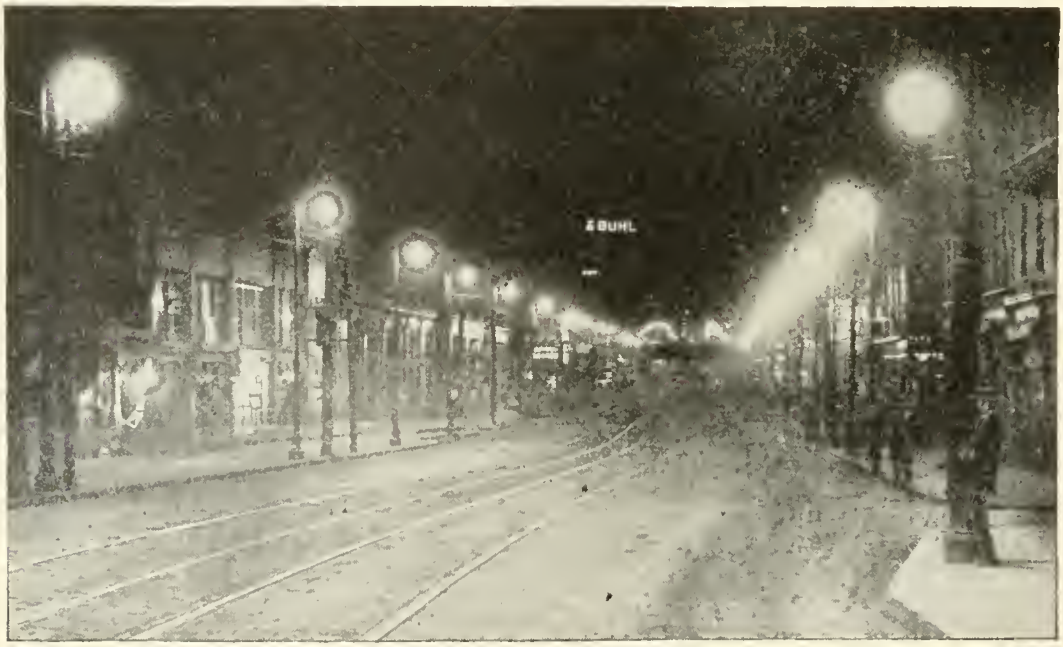


FIG. 1—WHITE WAY LIGHTING, FEDERAL STREET, PITTSBURGH, PA

This table indicates that aesthetic qualities are always of less importance than protection and comfortable vision, but sometimes more and sometimes less important than initial or operating costs. The determination of their position in the table is purely a consideration of available capital, and should be handled with an aim at economy, and in many cases more thought should be given to annual maintenance costs than to the initial cost. Instead of closing a contract for a certain amount for which is obtained a certain number of units of attractive and ornamental design, giving a certain candle-power, the street lighting committee should see that plenty of light is supplied, the number of units per lineal foot of street being indicated; that the design and outline of the post not only is in accord with the surrounding architectural scheme, but permits a mounting height that will give the very best illuminating features, i.e., lack of glare, proper direction of light rays, and desirable color and intensity of light; that the power consumption per lineal foot of street will be maintained within reasonable range of a predetermined minimum; that the initial cost of the installation will be economical; and, that once the equipment is in operation, the annual costs will not be prohibitive, thus assuring long life of all the good qualities of the improved systems.

TABLE I—RELATIVE VALUES OF ILLUMINATION FEATURES

Business Streets	Residential Streets	Suburban Districts, Parks and Boulevards
1—Protection	1—Protection	1—Protection
2—Comfortable Vision	2—Comfortable Vision	2—Comfortable Vision
3—Advertisement	3—Minimum Maintenance Cost	3—Minimum Maintenance Cost
4—Aesthetic Value	4—Aesthetic Value	4—Minimum Initial Cost
5—Minimum Maintenance Cost	5—Minimum Initial Cost	5—Aesthetic Value
6—Minimum Initial Cost	6—Advertisement	6—Advertisement

BUSINESS STREET LIGHTING

Every wide-awake merchant knows that improved street lighting is a big advertisement and increases trade. He knows that his competitor gets his business if he fails to be up to date in illumination. Merchants in one section, appreciating this, club together and the street lighting improvement is pushed. Such movements are bringing forth "White Ways" in a great many active cities. Here decorative units are well worth while, and considerable expense is warranted, the profit on the investment appearing in increased business. Recently a "White Way" system was installed in Pittsburgh, the advertising benefits from which are already in evidence. The installation consists of the latest type of long life flame carbon arc lamp mounted on ornamental posts, and shows the effects of careful consideration of the points outlined in Table 1. An idea of the appearance of this lighting system may be obtained from Fig. 1. To meet the requirements set forth in Table 1 for business lighting, Fig. 2 offers a suggestion. Due to the use of high intensity illuminants a less number of units is needed, thus assuring minimum initial and maintenance costs. The post presents an attractive appearance and allows a proper mounting height. When flame carbon arc lamps are mounted lower than 25 feet from the street, opalescent glassware reduces the glare and adds to the appearance of the unit.

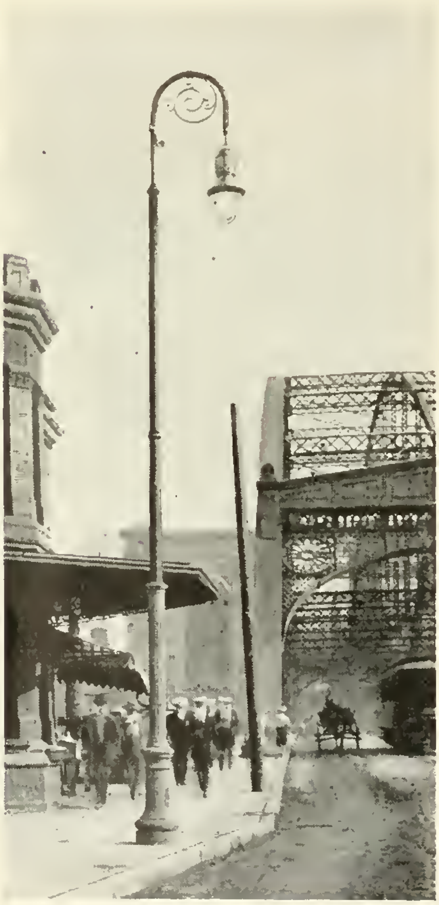


FIG. 2—ORNAMENTAL POLE USED FOR LIGHTING SHOWN IN FIG. 1

RESIDENTIAL STREET LIGHTING

In residential districts the street lighting is usually paid for by city taxes. Hence it is desirable to keep the cost of the system low. The mercantile world is absent here and cannot be depended upon to back improved street lighting, no advertising value being attained at such a distance from the business center. Protection and comfortable vision are very important. Although the traffic is not so heavy as in the downtown districts, the pedestrian is on the lookout for the approaching automobile. Protection from motorists who exceed the speed limit in our heavily foliaged residential sections requires proper illumination. The placing of high candle-power units at about the level of the drivers' eyes should be prohibited.

On this score the following is quoted from "Ornamental Street Lighting," published by the National Electric Light Association: "Take the matter of glare, for example. Glare is the result of looking at a light, instead of seeing by it. Better than any man, the motorist knows what glare is. When he drives from a dark spot toward an intense light, he finds that he cannot see beyond the light; accordingly he sits back and trusts to luck that there is no person or obstruction beyond."

The value of aesthetic qualities for residential streets is, of course, appreciated. Nothing should be used as a lighting unit that will detract from its beauty. On the other hand, the installation of costly conduit service and highly ornamented posts at the sacrifice of proper mounting heights and of other desirable illumination features is to be discouraged. However, the matter of selecting units for this class of lighting is very difficult. A variety of conditions exist satisfied by no one type. Where heavy foliage exists, small units of low candle-power mounted just below the foliage and at frequent intervals will readily meet with approval, especially if they do not detract from the architectural and landscape environment. Fig. 3 is an excellent representation of the combination of serviceable and ornamental qualities. The construction is unique and shows thorough consideration of the rela-

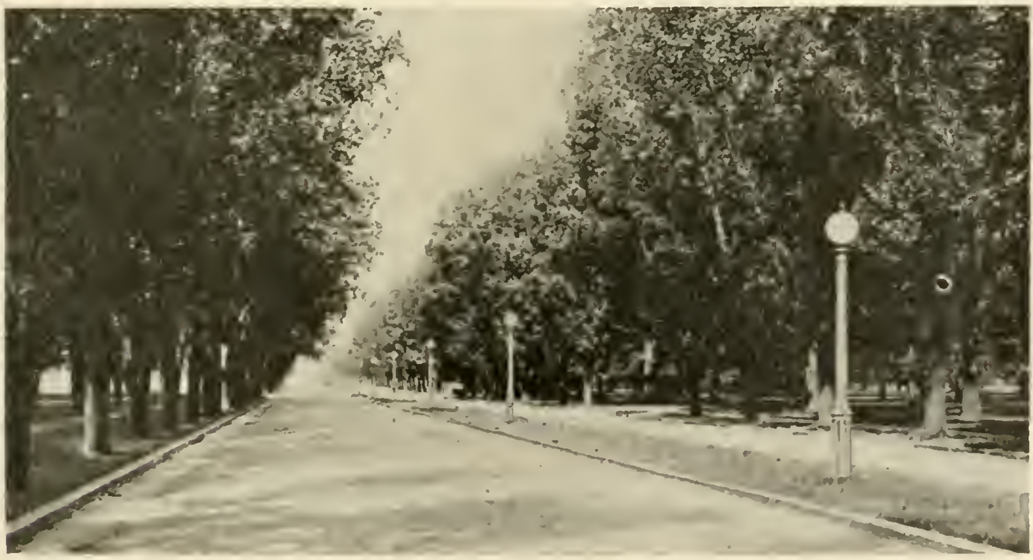


FIG. 3—BOULEVARD LIGHTING BY TUNGSTEN LAMPS ON ORNAMENTAL POSTS IN STRIPS OF PARKING IN CENTER OF ROADWAY

tion of initial costs to aesthetics. It is adaptable to pathways in public parks, boulevards or residential districts. Series tungsten units are most frequently used to advantage. This system gives considerable flexibility when operated as part of a direct-current rectifier circuit. Metallic flame lamps at four amperes give excellent illumination for places where little foliage is found, and tungsten lamps can be used on low ornamental brackets or posts such as shown in Fig. 4, where trees predominate.

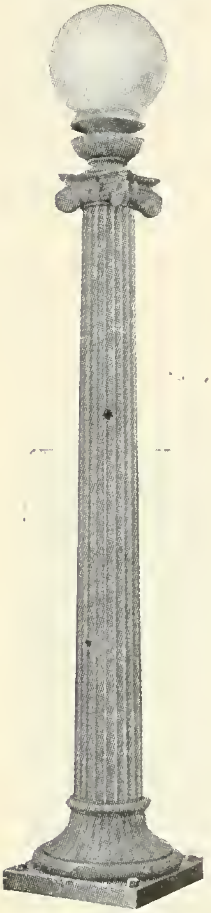


FIG 4—ORNAMENTAL POST FOR TUNGSTEN LAMPS*

THE LIGHTING OF SPARSELY POPULATED DISTRICTS

This class of lighting may well be subdivided, because, for boulevard and park lighting it is often desirable that considerable stress be laid on aesthetic features, while the problem of selecting a unit for outlying districts of a city necessitates careful attention to costs, inasmuch as it is desirable to keep the initial and maintenance costs per unit length of street very low, because of the small amount of traffic and a minimum number of pedestrians. A careful study of this class of lighting problem will show that the decorative value ranges anywhere between the third position for beautiful parks and boulevards to sixth position for outlying sparsely populated districts.

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*By courtesy of the Union Metal Mfg. Company, Canton, Ohio.

SHOP TESTING OF ELECTRICAL APPARATUS

II—RESISTANCE MEASUREMENTS

RESISTANCE measurements are used in the calculations of temperature rises, in the calculation of efficiency by losses, in the preparation of circle diagrams of induction motors, as checks both on design and on workmanship, and in various other ways. Hence accuracy of measurement is of considerable importance. This involves in turn accurate standards, which in the majority of resistance measurements means accurately known units of resistance. The unit of resistance in common use is the ohm. It is defined as the resistance of a column of pure mercury 106.3 cm. long, of uniform cross-section and weighing 14.4521 grammes at zero degrees *C*. As this unit is too unwieldy for practical work, secondary standards of special resistance wire, having a zero temperature co-efficient, have been established. Massive terminals, arranged to dip into mercury cups, provide minimum contact resistance. Such a standard can be made exceedingly accurate, but it is also somewhat unwieldy for everyday use, and boxes containing lengths of wire of known resistance are used for ordinary testing. By inserting or removing metal plugs the resistance between terminals of such boxes can be varied over a wide range. The resistances are made non-inductive by doubling the wire, before it is wound on the spool, so that the inductive effect of each turn is neutralized by the adjacent turn. With such a resistance box great care must be taken to keep the plugs and contact surface clean, as otherwise errors are liable to result. The surface of the plugs and the holes between the blocks should frequently be cleaned with coarse paper or waste. They should never be cleaned with emery paper, as this is liable to change their shape and prevent perfect contact. In using such a box all the plugs should be carefully tightened before each measurement is taken.

METHODS OF MEASURING RESISTANCES

There are two methods in common use for measuring resistances, each one of which is capable of many variations. The fall of potential method involves no standards of resistance and is applicable over wide ranges of resistance measurements. Its accuracy is dependent upon the accuracy of the instruments used in determining the current and voltage and upon the accuracy of reading the instruments. As two instruments must be read simultaneously the chances for error are therefore larger than in Wheatstone bridge methods. The ammeter always measures the current which passes through the voltmeter; for high resistance measurement with a high resistance voltmeter this is negligible, but for low resistance measurements, with a milli-voltmeter, this may introduce an appreciable error unless corrected. A source of power is always necessary, and, if the voltage be fluctuating, accurate measurements are difficult. More time is usually required to measure resistances by this method than by the bridge methods, and if too large a current is used, the resistance being measured will change owing to temperature rise. For these reasons, resistance measurements are ordinarily made by comparing the unknown resistance with some known resistance. This is usually done by some form of Wheatstone bridge.

Fall of Potential Method—This method of resistance measurement is dependent upon Ohm's law, namely that the resistance in ohms equals the drop in potential across the resistance, measured in volts, divided by the current flowing through the resistance in amperes. To make use of this method a current of suitable value is passed through the resistance to be measured, with an ammeter in the circuit to determine exactly the current value. Leads from a voltmeter of suitable range are connected across the terminals of the resistance. Usually several readings are taken with different current values and the average of the resistances, computed from each set of readings, is taken as the true value. Care must be exercised that the voltmeter leads are placed so that the resistance of the contacts between the unknown resistance and the source of power is not included. The voltmeter and ammeter readings should be made simultaneously.

If an ammeter is not available, the current can be determined by connecting a known resistance in series with the unknown and taking the drop of potential across both the known and unkown resistances. The resistances are then in direct proportion to the potential drops. The resistance of an ammeter, or any current measuring instrument, can be determined simply by taking the drop in potential over its coils with a low reading voltmeter and simultaneously noting the reading of the ammeter.

When very high resistances, such as the resistance of the insulation of a generator, are to be measured, a single voltmeter of known resistance can be employed in place of a voltmeter and ammeter. The voltmeter is first connected across the line and the exact line voltage determined. The same voltmeter is then connected across the same source of potential with the unknown resistance in series and a reading taken. Then $V : v = (r + R) : r$ whence $R = r (V - v) \div v$, where r = the known resistance of the voltmeter, R = the resistance to be measured, V = the reading of the voltmeter without the resistance in series, v = the reading of the voltmeter with the unknown resistance in series.

The voltmeter method of measuring extremely high resistances is fairly accurate, but involves a certain amount of calculation before the results can be determined and requires a source of potential, which cannot always be secured. In order to avoid this, a direct reading resistance meter known as a "megger" is in common use. This instrument contains permanent magnets so placed that a nearly closed magnetic circuit is formed, the magnetic circuit being shown diagrammatically in Fig. 1. The moving system consists of a coil *A*, which is conected in series with the resistance to be measured; and a pair of coils connected in series marked *B* and *B′*, which, with the resistance *R*, are connected directly across the dynamo terminals, the three coils being connected rigidly together. There are no springs, the position of the pointer being determined by a balance of magnetic reactions between the coils *A*, *B*, *B′* and the permanent magnets. The scale reading is directly in ohms, and is independent of the speed of the generator and of the strength of the permanent magnets. A friction device is provided whereby the speed of the generator is constant above a certain speed of the driving handle, since it is necessary to have an approximately fixed e.m.f. in measuring the insulation resistance of

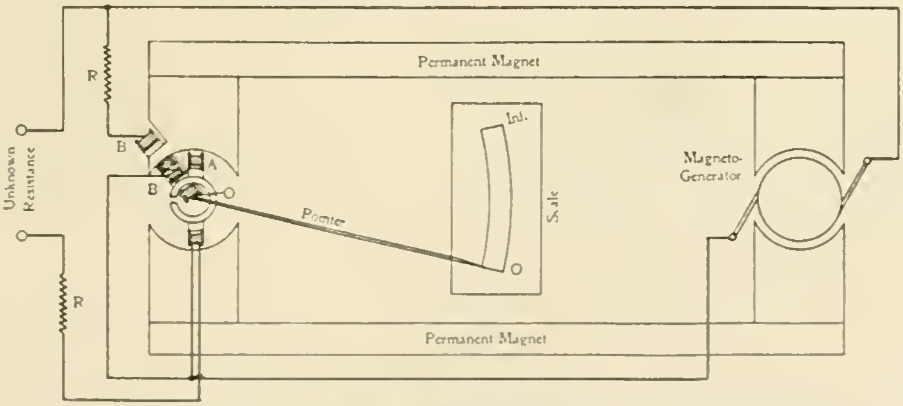

FIG. 1—SCHEMATIC DIAGRAM OF MAGNETIC CIRCUIT AND ELECTRICAL CONNECTIONS OF MEGGER*

a machine whose windings have considerable capacity. No reading should be taken on such a machine until it has become fully charged, as indicated by a constant reading of the instrument.

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*By courtesy of James G. Biddle, Philadelphia, Pa.

Bridge Methods of Measurement—The combination of conductors and resistances shown in Fig. 2 is known as a Wheatstone bridge. In this diagram, *A, B* and *R* are known resistances, at least one of which must be adjustable, and preferably all of them, while *X* represents the unknown resistance whose value is to be determined. *G* represents a galvanometer, which need not necessarily be calibrated, as measurements are taken by the "null method," that is by bringing the system to a condition of balance, such that no galvanometer deflection is secured. When such a combination of resistances has been secured by adjusting the known resistance, then A : B = R : X, and X = R×B÷A.

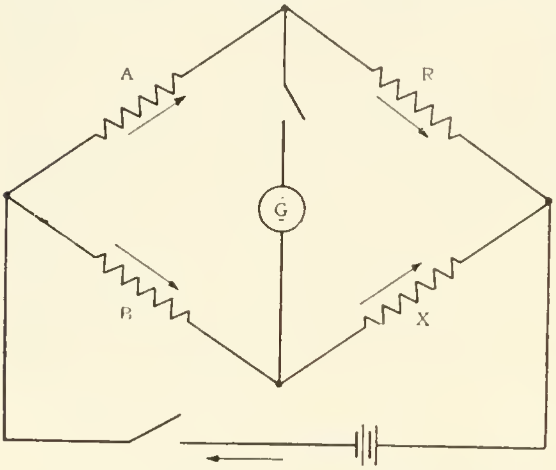

FIG. 2—DIAGRAM OF WHEATSTONE BRIDGE

In order to facilitate resistance measurements, the known resistances *A, B* and *R* are frequently combined in one box together with a galvanometer. The resistances are interconnected in such a way that only four binding positions are necessary, two for the battery and two for the unknown resistance. Such a combination of resistances is frequently known as a Post Office box, or plug type Wheatstone bridge. The ratio resistances, *A* and *B,* are frequently formed by two parts of a straight wire of uniform cross-section, as shown in Fig. 3, the ratio being varied by the sliding contact. The slide wire is made of a non-corrodible metal of a high specific resistance and preferably of zero temperature coefficient. After balance is obtained, the calculations are as before.

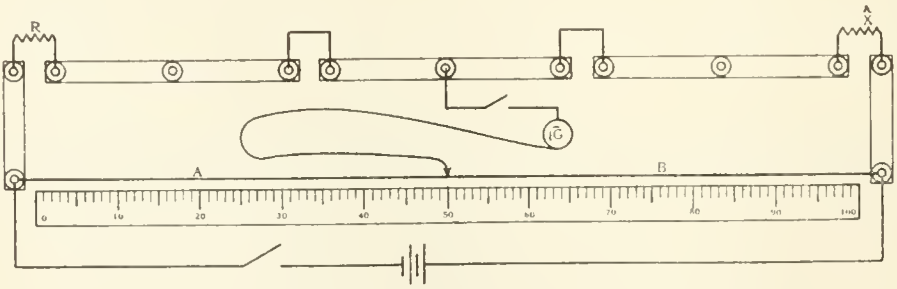

FIG. 3—SLIDE WIRE TYPE OF WHEATSTONE BRIDGE

There are two general methods of combining the coils in a resistance box intended to be used with a Wheatstone bridge. The first, known as the 1, 2, 3, 4 plan or the 1, 2, 2, 5 plan for coils representing corresponding values in ohms and also multiples of these values by 10-100-1 000, all connected in series. By pulling out suitable plugs any desired value of resistance may be secured with a minimum number of resistance coils, and hence this method is customary where cost of the resistance box must be kept as low as possible. The disadvantages of this method are that a number of plugs must be pulled out to obtain any definite reading and all the plugs which are not pulled out must be set very tightly in place. The resistance of the box at any time must be determined by adding

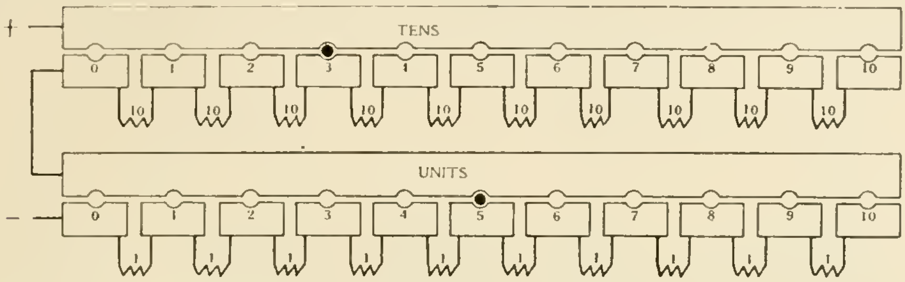

FIG. 4—DECADE ARRANGEMENT OF RESISTANCE BOX

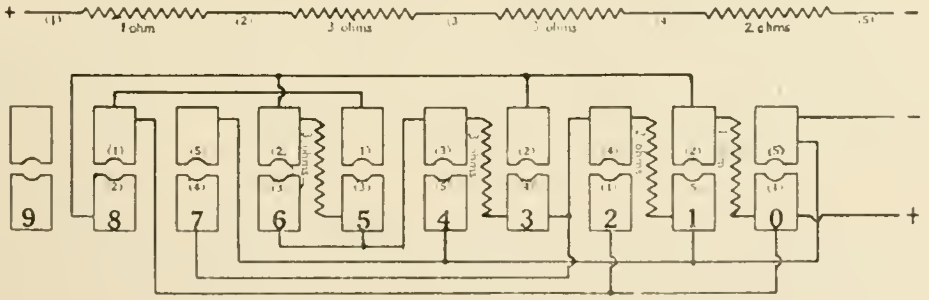

FIG. 5—DECADE ARRANGEMENT OF FOUR COILS*

The numbers at the contact represent the corresponding points on the diagram at the top. The points which must be connected to secure any value, and the coils connected in series are:—

Value.	Points.	Coils.	Value.	Points.	Coils.
0	5 and 1	0	5	1 and 3	3+2
1	2 and 5	1	6	2 and 3	1+3+2
2	4 and 1	2	7	5 and 4	1+3+3
3	2 and 4	1+2	8	1 and 2	3+3+2
4	3 and 5	1+3	9	0	1+3+3+2

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*Much of the information contained herein concerning Wheatstone and Kelvin Bridges was obtained through the courtesy of Leeds & Northrup Company, of Philadelphia.

the numbers corresponding to the plugs pulled out. These disadvantages have led to the development of what is known as the "decade" plan, in which there are either 9 or 10 one-ohm coils for the units place, 9 or 10 ten-ohms coils for the tens place and so on, as shown in Fig. 4. Each group of coils of the same value is known as a decade. It is apparent that any value in any one decade can be obtained by inserting only one plug between the bar and the block, and where several decades are in series, the resistance of the box at any setting can be read off directly from the position of the plugs without any addition. Only nine coils are necessary in any decade to make a complete succession of values, but it is customary to use ten in order that one coil in any decade can be checked against all the coils in the next lower decade in series, or of the next higher decade in parallel. The disadvantage of the decade arrangement is the expense of having the large number of coils. This can, however, be avoided by grouping four coils in such a manner that inserting the proper plug in the decade will secure the proper resistance, as shown in Fig. 5. The decade arrangement of resistance is also well adapted to the use of dial-switches, which are sometimes found more convenient than the ordinary arrangement, and, if properly made, are quite accurate.

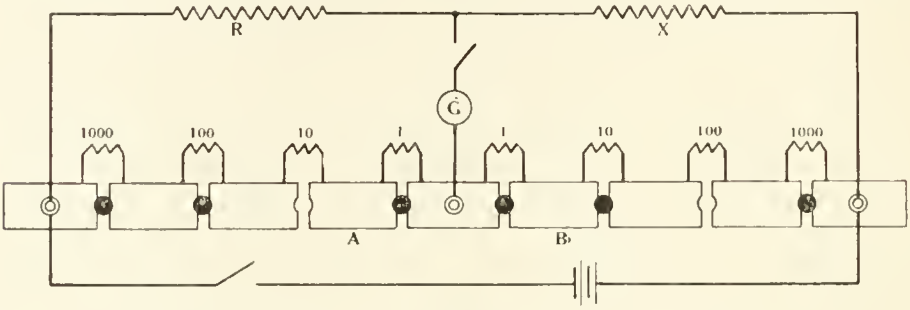

FIG. 6—USUAL ARRANGEMENT OF RATIO COILS FOR WHEATSTONE BRIDGE

Resistances not wanted are short-circuited by plugs. Coils above are plugged for a ratio of 10:100.

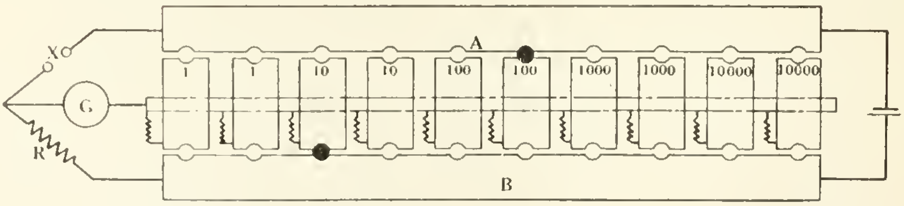

FIG. 7—IMPROVED ARRANGEMENT OF RATIO COILS

One plug is set opposite any resistance desired. The ratio indicated in the diagram is 10:100.

The decade arrangement of resistances ordinarily applies to the resistance *R*, Fig. 2. The ratio coils *A* and *B* are usually arranged as shown in Fig. 6. This is the simplest form, but it is open to the objection that for very accurate work the contact resistance of the plugs which remain in, is included with the unplugged resistance. It is also impossible to transpose the arms of the bridge *A* and *B*, which is sometimes desirable. A set of reversing plugs which is frequently added to overcome this difficulty adds still more contact resistance. This difficulty can be overcome by the use of the type of ratio arm illustrated diagrammatically in Fig. 7. By this method, two plugs only are necessary, one being inserted betwen the bar *A* and the desired resistance, and the other between bar *B* and the resistance for the other arm. With this arrangement the ratio arms can be interchanged at will, and there is no necessity for more than two plugs.

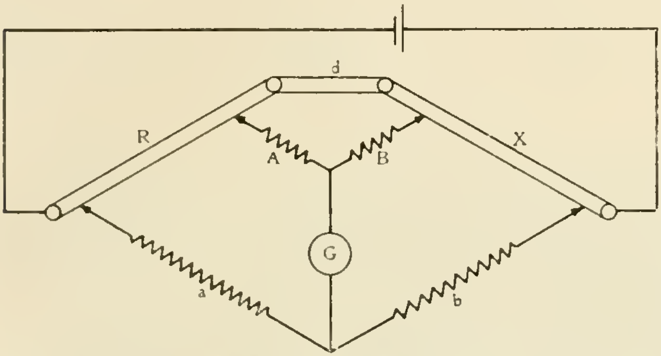

FIG. 8—DIAGRAM OF KELVIN BRIDGE METHOD OF MEASURING LOW RESISTANCES

The Wheatstone bridge method of measuring resistance is satisfactory for values between 1 and 10 000 ohms. Where lower values are to be measured, a modification, such as shown in Fig. 8, is necessary. This method, devised by Lord Kelvin, is very satisfactory for measuring resistances as low as 0.0001 ohm, and is especially valuable in that the resistance of the contacts is not included, and hence no special pains are necessary to secure good electrical joints, except to minimize the heating effect. *R* and *X* are two low

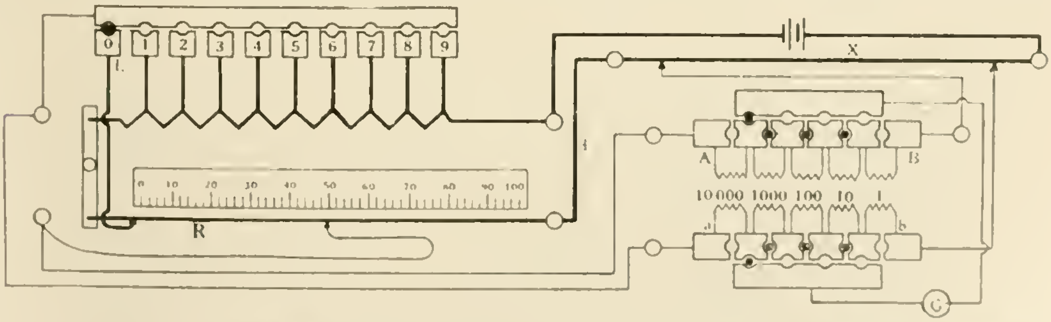

FIG. 9—USUAL ARRANGEMENT OF RESISTORS FOR KELVIN BRIDGE MEASUREMENTS

The rough adjustment of *R* is made with the plugs at *L*, the fine adjustment by the slide wire. The ratio A:B must always equal a:b. In the diagram A:B=a:b=10 000 to 1.

resistances with potential terminals which are to be compared with each other, *d* is a low resistance piece connecting them, and *a* and *b* and *A* and *B* are variable resistances of known value. There will be no current passing through the galvanometer *G*,

$$\text{when,—}\quad \frac{R}{X}=\frac{a}{b}+\frac{d}{X}\times\frac{B}{A+B+d}\times\left(\frac{a}{b}-\frac{A}{B}\right)$$

When $\frac{a}{b}=\frac{A}{B}$ the last member of this equation becomes zero and the equation reduces to the simple form $\frac{R}{X}=\frac{a}{b}=\frac{A}{B}$

The practical application of this method is shown in Fig. 9, which for convenience is lettered the same as Fig. 8. In this figure *X* represents the unknown resistance, *R* represents a slide wire of known resistance between points *0* and *100*, and the ratio resistances *a*÷*b* and *A*÷*B*, which are exact duplicates, should be plugged alike. The resistance of *R* can readily be determined from the scale, and the value of the unknown resistance is then determined from the equation $X=\frac{Rb}{a}=\frac{RB}{A}$ It will be noted that the resistance of the arm *R* is equal to the sum of the resistance of the slide wire plus the resistance plugged in at *L*.

For resistances between 5 and 10 000 ohms, the Wheatstone bridge method is preferable, while for resistances above 10 000 ohms the Wheatstone bridge method is not as accurate as either the voltmeter of known resistance or the megger method. For resistances between 5 ohms and 0.0001 ohm the Kelvin bridge method is preferable, but for lower resistances than this, such as the series coils of large capacity generators, large capacity ammeter shunts and secondaries of large capacity low potential transformers, the only satisfactory method is by drop of potential. A resistance table equipped with both Wheatstone and Kelvin type bridges for all varieties of resistance measurements is shown in Fig. 10. The batteries and rheostats for controlling the current are mounted on the lower part of the truck, while the table proper is spring supported, in order to prevent breakage of the fine wires in the resistance boxes by sudden shocks. The jeweled instruments are removed from the table while it is being wheeled about.

Resistance Measurements for Determining Rise of Temperature—This method consist in taking the resistance of the coil at the room temperature and noting carefully the temperature of the winding as indicated by a thermometer. The resistance of the coil is again taken after a normal run at full load or after any desired test has been made. This can be done by any suitable method, but in order to combine it with other tests it is ordinarily done by the drop of potential method. The temperature is then calculated from *Formula 5*, given later. In order to determine the temperature at some specific location in a large coil, either a field coil or an armature coil, a resistor composed of very fine wire and of very small dimensions is placed inside the slot at the point where the temperature is desired and fine leads are brought to the outside of the machine. The temperature is calculated by the change in resistance in this small test coil. In place of the small resistance coil, a small thermo-couple is also used for the same purpose. The thermo-couple is more commonly used for this purpose and

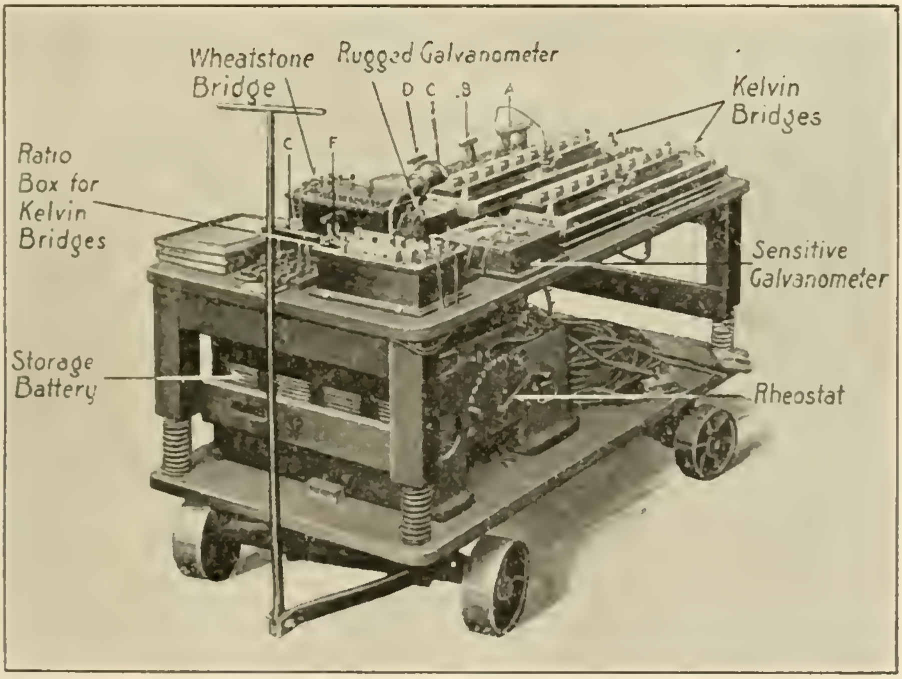

FIG. 10—RESISTANCE TESTING TABLE

This table contains apparatus for resistance measurements from 0.0001 to 10 000 ohms, including two Kelvin bridges and Wheatstone bridge. Preliminary adjustments are made with the rugged galvanometer, and the final adjustments with a galvanometer of great sensitiveness. Current is conveyed to the apparatus to be measured through the heavy clamps shown at the lower right hand corner, being limited by the rheostat for low resistance measurements. Switch *A* switches the current from one Kelvin bridge to the other. Switch *B* switches the galvanometer circuit from the Kelvin bridge to the Wheatstone. Switch *C* is the line switch, opening the battery circuit. *D* serves to change the batteries from parallel to series connection. *F* changes from the rugged to the sensitive galvanometer and *G* reverses the direction of the ratio coils so as to multiply or divide by the ratio set.

is connected to an indicating pyrometer, which consists of a differentially wound milli-voltmeter so arranged as to allow the use of a battery for actuating the coils, but with the position of the needle determined by the e.m.f. generated in the couple. For still more accurate results the e.m.f. of th thermo-couple is balanced by a potentiometer. In measuring resistances to determine rises of temperature, care must be exercised that contacts are made at the same points for both the cold and hot measurements, and that no temporary contacts are included in the measurements, as the contact at such places is occasionally improved to such an extent by the expansion of the metal as to give a lower resistance when hot than cold. It is customary to mark the points between which resistances are taken with a punch mark or in some other suitable way.

TABLE I—COEFFICIENTS FOR CHANGING THE RESISTANCE OF COPPER

At any observed temperature to the equivalent resistance at 25 degrees C. Coefficient of 0.0042 at 0 degrees C. taken as base.

Observed Temp.	Coeff.	Observed Temp.	Coeff.	Observed Temp.	Coeff.	Observed Temp.	Coeff.	Observed Temp.	Coeff.
10	1.0604	16	1.0355	22	1.0116	28	.9889	34	.9670
¼	1.0594	¼	1.0344	¼	1.0106	¼	.9880	¼	.9661
½	1.0583	½	1.0334	½	1.0096	½	.9871	½	.9652
¾	1.0573	¾	1.0324	¾	1.0085	¾	.9860	¾	.9643
11	1.0562	17	1.0314	23	1.0076	29	.9850	35	.9634
¼	1.0552	¼	1.0304	¼	1.0066	¼	.9841	¼	.9625
½	1.0541	½	1.0294	½	1.0057	½	.9831	½	.9616
¾	1.0531	¾	1.0283	¾	1.0048	¾	.9822	¾	.9607
12	1.0520	18	1.0273	24	1.0038	30	.9813	36	.9599
¼	1.0509	¼	1.0263	¼	1.0029	¼	.9804	¼	.9590
½	1.0499	½	1.0253	½	1.0019	½	.9795	½	.9581
¾	1.0488	¾	1.0243	¾	1.0010	¾	.9786	¾	.9572
13	1.0477	19	1.0233	25	1.0000	31	.9777	37	.9564
¼	1.0467	¼	1.0223	¼	.9991	¼	.9768	¼	.9555
½	1.0457	½	1.0213	½	.9980	½	.9759	½	.9546
¾	1.0446	¾	1.0204	¾	.9971	¾	.9750	¾	.9538
14	1.0436	20	1.0194	26	.9962	32	.9741	38	.9529
¼	1.0426	¼	1.0184	¼	.9952	¼	.9732	¼	.9521
½	1.0415	½	1.0174	½	.9943	½	.9723	½	.9512
¾	1.0405	¾	1.0165	¾	.9934	¾	.9714	¾	.9503
15	1.0395	21	1.0155	27	.9925	33	.9705	39	.9495
¼	1.0385	¼	1.0145	¼	.9916	¼	.9696	¼	.9486
½	1.0375	½	1.0135	½	.9907	½	.9687	½	.9478
¾	1.0365	¾	1.0126	¾	.9898	¾	.9679	¾	.9469

All resistances should be recorded exactly as measured, but the one computing the results should reduce the readings to resistances at a standard room temperature of 25 degrees C., before tabulating. This value may be determined from the following formula:

$R—25^\circ\ C. = \frac{238+25}{238+t} \times R$ at t° C., where *t* equals the actual temperature of the air. In the case of the cold resistance this must be the same as the temperature of the windings, but for hot resistance it is the average of the air temperature during the last quarter of the run. The value of $\frac{238+25}{238+t}$ for all temperatures from 10 to 40 degrees C. is given in Table I. The rise in temperature in degrees C. may readily be determined from the change in resistance, provided the rate of change with temperature is known. It has been established that the resistance of a copper conductor increases 0.42 percent for each degree C. increase in temperature, the resistance at zero being assumed as 100 percent.

In the following formulae let,—

Ro = The resistance of a certain winding at 0 degrees, C.
Rt = The cold resistance of the same winding at *t* degrees, C.
Rt_1 = The hot resistance of the same winding at t_1 degrees C.

$$Rt = Ro\ (1 + 0.0042\ t) = Ro\ \left(1 + \frac{t}{238}\right) \text{ or } Ro = Rt\ \frac{238}{238+t} \qquad (1)$$

$$Rt_1 = Ro\ (1 + 0.0042\ t_1) = Ro\ \left(1 + \frac{t_1}{238}\right), \text{ or } Ro = Rt_1\ \frac{238}{238+t_1} \qquad (2)$$

Combining (1) and (2) gives the fundamental formula for changing a resistance at one temperature to that at any other,

$$\frac{Rt}{Rt_1} = \frac{238+t}{238+t_1}. \qquad (3)$$

Solving now for t_1,—

$$t_1 = \frac{Rt_1\ (238+t)\ —\ 238\ Rt}{Rt} = \frac{Rt_1}{Rt}\ (238+t)—238 \qquad (4)$$

This is the actual temperature in degrees C., or the rise above zero degrees. If the rise above *t* degrees is desired, *t* should be subtracted from both sides of the above equation and the formula will become,

$$t_1 — t = \frac{Rt_1\ (238+t)\ —\ 238\ Rt}{Rt} — t = \frac{Rt_1 — Rt}{Rt}\ (238+t) \qquad (5)$$

Formula 5 is the standard formula for determining the rise by resistance. The temperature rise here determined may be due to two conditions: primarily to current flowing in the winding, and secondarily to change in temperature of the surrounding air. To eliminate this secondary change both cold and hot resistances must be reduced, by the use of formula 3, to a common room temperature before being used in formula 5. If the rise above 25 degrees C is desired, which is in accordance with the standardization rules of the A.I.E.E., that must be the common temperature.

EFFICIENCY OF SYNCHRONOUS BOOSTER ROTARY CONVERTERS

J. L. McK. YARDLEY

As not all of the factors involved in determining the efficiency of the synchronous booster rotary converter are generally understood, a brief explanation of this subject may prove of interest. The losses which are usually taken into consideration in determining the efficiency by the separate loss method are as follows:

1—Bearing friction and total windage.
2—Brush friction.
3—Rotary converter iron loss.
4—Rotary converter shunt field I^2R loss.
5—Rotary converter armature I^2R loss.
6—Rotary converter commutating pole series field I^2R loss.
7—Rotary converter commutating pole auxiliary field I^2R loss.
8—Booster field I^2R loss.
9—Booster armature I^2R loss.
10—Booster iron loss.

After the machine has been operated until mechanical conditions have become uniform, the losses *1* and *2* may be considered to remain constant for all loads, assuming of course a constant frequency. These losses are obtained by reading the input to a separate driving motor. Losses *3* and *10* are taken from the iron loss curves obtained by driving the booster converter at synchronous speed by a separate driving motor. Loss *4* is obtained by observing the field current under the particular load conditions at which the efficiency is being calculated and multiplying the ampere value so read by the exciting voltage. Loss *6* is obtained by multiplying the square of the field current by the field resistance at 60 degrees C. Losses *7* and *8* are figured together (since these two fields are connected in series) by multiplying the field current by the exciting voltage. The exciting voltage for *4*, *7* and *8* is usually the direct-current terminal voltage of the rotary converter. Losses *5* and *9* vary considerably for a constant direct-current output, depending upon the actual amount of boost. When the boost is positive, the booster is raising the direct-current voltage. It is then acting as a generator, being driven mechanically by the converter acting as a synchronous motor. When the boost is negative the booster is lowering the direct-current voltage; it is then acting as a motor, delivering power mechanically to the converter which, under this condition, delivers some of its direct-current output as a direct-current generator. In the one case, the additional current (flowing in the main rotary converter armature winding) is an alternating current; in the other, a direct current. In either case it is proportional to the percent boost, and in figuring the additional armature losses it may be considered in each case to be a direct current, as the calculation is thereby made simpler. The losses *5* and *9* may then be obtained by substituting values in the following equations:—

Under all conditions,— $\text{Loss } 9 = \left[(1+X) I_2 \right]^2 \frac{R_2 N}{P}$

When there is no boost,— $\text{Loss } 5 = E I_1^2 R_1$

When the boost is positive, $\text{Loss } 5 = E I_1^2 R_1 + R_1 \left\{ \left[(1+X) I_1 \right]^2 - I_1^2 \right\}$

When the boost is negative,—

$$\text{Loss } 5 = E R_1 \left[(1+X) I_1 \right]^2 + R_1 \left\{ I_1^2 - \left[(1+X) I_1 \right]^2 \right\}$$

In which,—

E = ratio of rotary converter armature loss as a converter to same as a direct-current generator.
I_1 = direct current flowing from rotary converter terminal*.
R_1 = rotary converter armature resistance at 60 degrees C.
I_2 = alternating current per collector ring at normal voltage*.
P = pairs of poles on rotary converter or booster.
N = number of phases or collector rings.
R_2 = resistance at 60 degrees C. of one booster armature winding between collector ring and converter armature tap.
X = percent boost (The sign of X may be plus or minus).

A large synchronous booster rotary converter, recently designed by the writer, may be taken as an example to show actual values that may be obtained. The losses were as follows:—

Losses at 100 percent Power-Factor	Loss in Watts, with		
	Normal Voltage	Minimum Range	Maximum Range
Loss 1	21 400	21 400	21 400
" 2	6 170	6 170	6 170
" 3	13 900	8 800	20 100
" 4	16 600	11 100	25 800
" 5	37 600	65 800	81 000
" 6	21 400	21 400	21 400
" 7	0 }	9 900	13 300
" 8	0 }		
" 9	15 850	11 500	20 800
" 10	0	4 600	4 600
Total losses....................	132 020	160 670	214 570
Output.........................	3 500 000	2 075 000	4 020 000
Input...........................	3 632 020	3 135 670	4 234 570
Total Efficiency, Percent........	96.3	95.0	95.0

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*If B = percent efficiency, of which a first approximation must be made, and C = ratio of alternating-current to direct-current voltage at normal voltage operation, then

$I_2 = \frac{I_1}{3BC}$ for six-phase converters; $= \frac{I_1}{2BC}$ for two-phase converters.

and $= \frac{I_1}{1.73BC}$ for three-phase converters.

SWITCHBOARDS FOR ALTERNATING-CURRENT POWER STATIONS--II

C. H. SANDERSON

SELF-CONTAINED SWITCHBOARDS OF 6 600 VOLTS OR LESS WITH OIL CIRCUIT BREAKERS AND BUS-BARS SUPPORTED FROM THE BACK OF THE PANELS

THE most common generating voltages used for alternating-current power stations of moderate capacity for the usual classes of electric service are 2 200 and 6 600 volts. The term, moderate capacity, when applied either to a generating station or to a single generating unit, conveys a very different meaning now than it did a few years ago. Our moderate capacities of to-day were then maximum capacities, but the switchboard problems were even more serious ones than those which confront the engineer today. They were then venturing into new and untried fields while now the results of their pioneering are being perfected. Twenty years ago the self-contained switchboard had the entire field to itself, as there was then no necessity for any other class. With the advent of 2 200 and 6 600 volt generators and transformers came many different types of high voltage air break switches, circuit breakers and plug receptacles, most of which were expensive, untrustworthy and even dangerous when compared with the oil insulated devices which have replaced them.

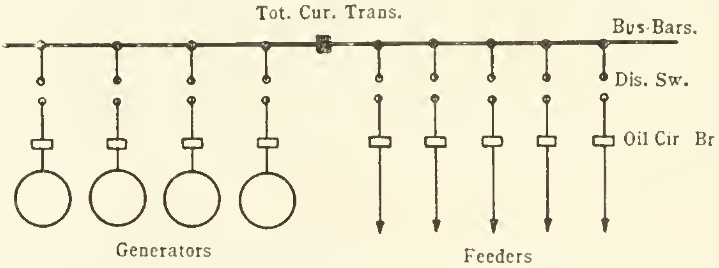

FIG. I—SINGLE BUS-BAR SYSTEM

Generators and feeders at opposite ends of bus-bars permitting use of totalizing instrument transformers.

APPLICATION

Experience has shown that for the usual conditions of service this class of switchboard should not be applied to stations whose capacity exceeds *2 500 k.v.a., three-phase, in high-speed turbo-generators, or *5 000 k.v.a., three-phase, in slow-speed engine type units. Moreover, it is not considered good practice to exceed 6 600

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*70 percent of this for single phase; 140 percent for two-phase.

volts, and it is usually advisable to confine its application to 2 500 volts or less. The reason for this limitation lies in the danger to attendants from high voltage apparatus when in close proximity to low voltage control and instrument wiring, rheostats, etc., which require inspection and occasional repairs. Also in the necessity, with the higher voltages, of longer and higher switchboards to gain sufficient spacing distances. It is recommended that the size of individual circuit-breakers and switches for this type of switchboard be limited to 600 amperes or less per pole on account of—

a—The advisability of limiting the amount of power handled by one circuit-breaker mounted directly on the panel.
b—Difficulty of obtaining adequate insulation distances between the heavy bus-bars and connections required for larger capacities.
c—The mechanical strains imposed upon the panels by the larger capacity circuit-breakers with their heavy connections, due both to their dead weight and to the shock of operation.

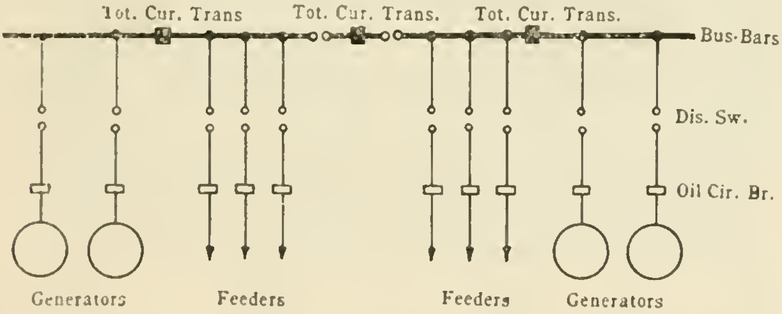

FIG. 2—SINGLE SECTIONALIZED BUS-BAR SYSTEM
Station may be operated in halves or as a unit as the load requires.

There may be conditions in certain installations where it is advisable to exceed these limits. No hard and fast rule can be made, as few installations are governed by the same conditions. The following suggestions, although applying to all boards of this class, should particularly be followed when the ultimate capacity connected to the bus-bars will be greater than the recommended limit:

The first consideration is the circuit-breaker. The type chosen should be of rugged design which will carry the rated current with not more than 30 degrees rise in temperature and which will not permit the escape of oil, either through leaking, creeping or expulsive effect of short-circuits. It should have a k.v.a rating, for instantaneous tripping, at least 25 percent in excess of the generating machinery to which it connects or, if relays with a definite time limit setting of two seconds or more are used, it should have 50 percent excess capacity.

If rubber covered wire is used for bus-bars or connections, it should be covered with a flame proof braid. The panels should be of sufficient width that there will be ample space between adjacent circuit-breakers in which to take away their leads. Instrument transformers should be rigidly secured to strong brackets to prevent vibrations due to heavy overloads or short-circuits.

The bus-bars should be as far apart as the design will conveniently permit and should be located near the top of the board. This arrangement places them out of reach of the attendants, at the same time giving accessibility to the back of the board, and also removes them from the immediate vicinity of the circuit-breakers.

Special precautions should be taken to insure that nothing can fall across the bus-bars or connections. Bus-bar screens or suitable insulation or both should be used. Insulation without screens is perhaps sufficient for bus-bars of small cross-section, but heavy capacity bus-bars require ventilation and for them this arrangement should be reversed.

Moving parts such as rheostat chains, mechanical connecting rods, etc., should be so arranged that their failure will not entangle other apparatus or cause short-circuits. They should be run in pipes or protected by shields where necessary.

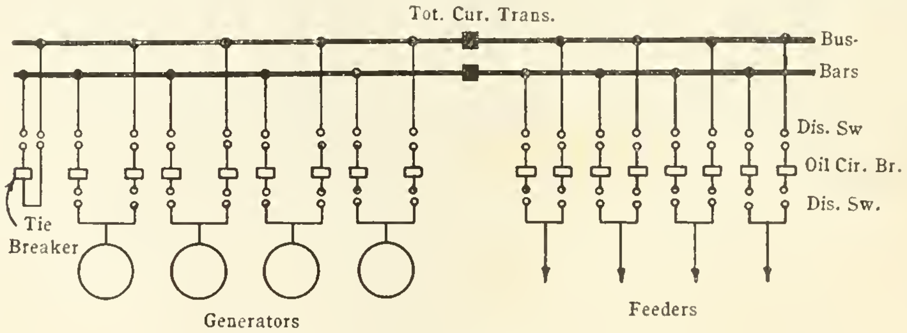

FIG. 3—DOUBLE BUS-BAR SYSTEM

Generators and feeders at opposite ends of bus-bars permitting use of totalizing instrument transformers.

CHOICE OF SYSTEM

The principal factors influencing the choice of the system are—the nature of the service to be supplied, the size and number of the units to be employed and the expense justifiable to give continuity of service. Other factors, such as a diversity of apparatus to be controlled, or the sequence of purchase, may have considerable influence in the choice and also in the growth of the system. Simplicity should be the principal aim. The simplest system which will do the work satisfactorily naturally represents the best engineering.

First and most usual is the single-throw system, Fig. 1. It is the least expensive as regards first cost, installation and maintenance, and lends itself readily to later additions or modifications.

It is used in all cases except where special requirements of the service or added precautions against failure of supply require modifications, such as in Fig. 2, or the adoption of the double-throw system, Fig. 3. The single-throw bus with tie circuit-breaker, Fig. 2, permits operation of a station in separate halves, which is particularly desirable where, for example, the left half of the bus may feed a railway, or other power load, while the right half feeds a lighting load. During the day while the power load is large and the lighting load is very small, the tie breaker is closed. When the lighting load comes on, the tie is opened; and, if later in the evening the power load disappears altogether, or its fluctuations are unobjectionable, the tie breaker may again be closed. The same procedure is possible where the double bus, Fig. 3, is employed. This system, though more complicated, more expensive, and requiring more space, gives great flexibility in the handling of load. Moreover,

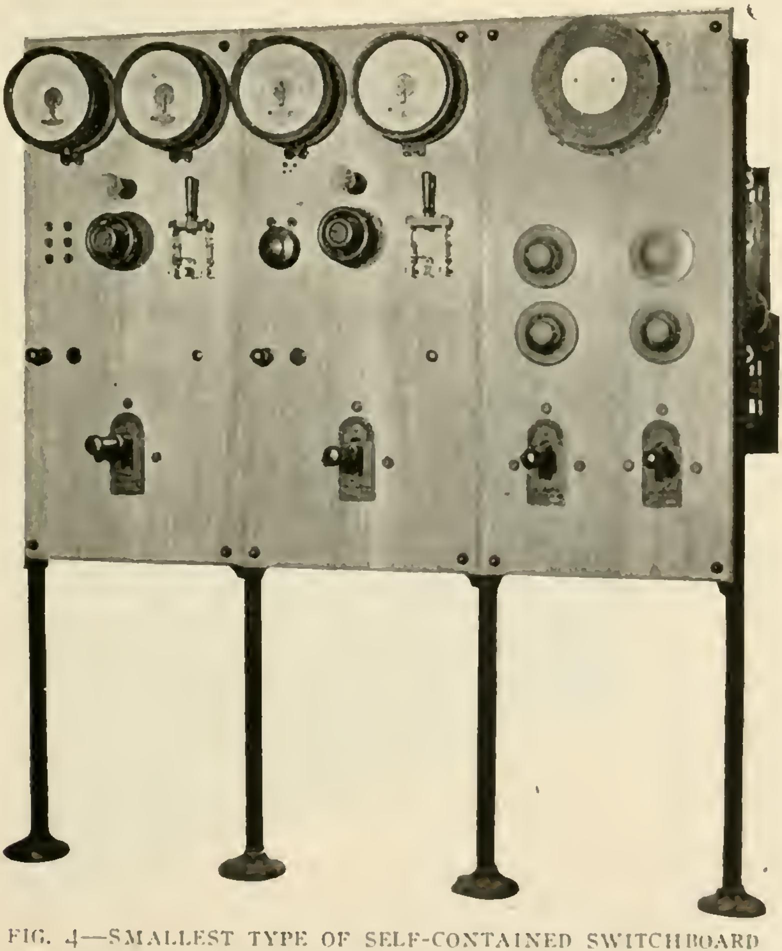

FIG. 4—SMALLEST TYPE OF SELF-CONTAINED SWITCHBOARD
Controlling two alternating-current generators with their exciters and two fused feeder circuits with totalizing watthour meters.

the double bus ordinarily gives adequate assurance of continuity of service, and permits of examination and repairs of any circuit breaker or connections thereto, or to either bus, without discontinuing any part of the service.

CHOICE OF APPARATUS

Standard panels containing standard apparatus for various classes of service are listed by the larger electrical manufacturing companies. Three distinct types are commonly provided for as follows:

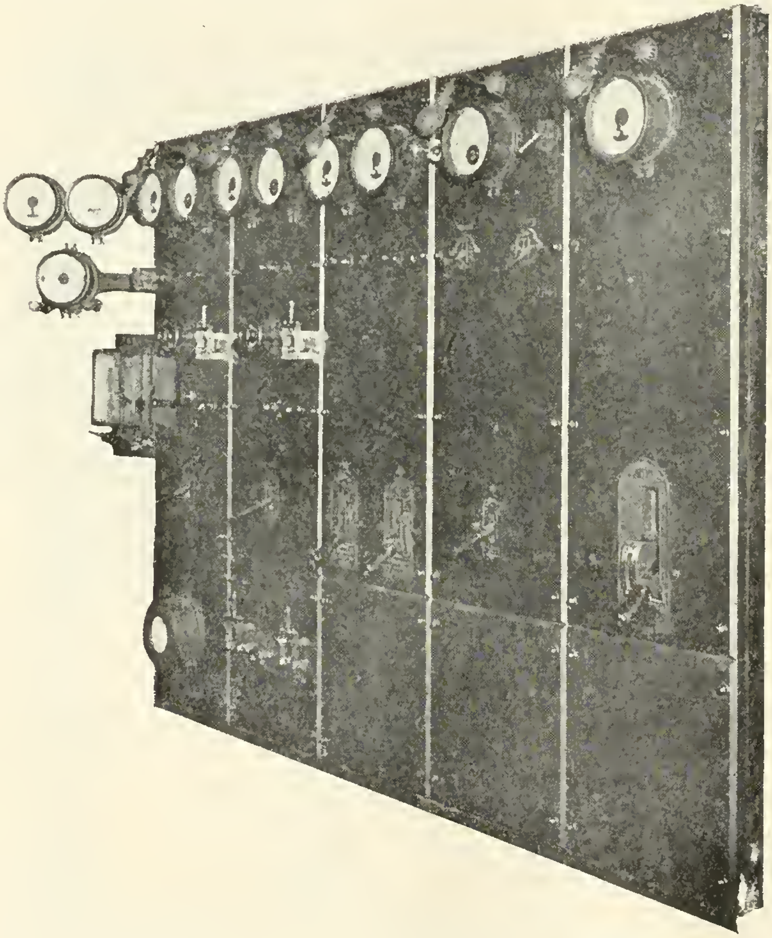

FIG. 5—MEDIUM SIZE SELF-CONTAINED SWITCHBOARD FOR FURNISHING LIGHT AND POWER FOR SMALL TOWN

Controls two alternating-current generators, with Tirrill regulator voltage control, two exciters, two power feeders, rectifier circuits for arc lights and alternating-current end of synchronous motor generator set for supplying direct-current.

1—The small plant where the most inexpensive board is desired, with only sufficient apparatus to fill the absolute requirements for operation of the plant, as in Fig. 4.

2—For plants of medium capacity larger switchboards are advisable,

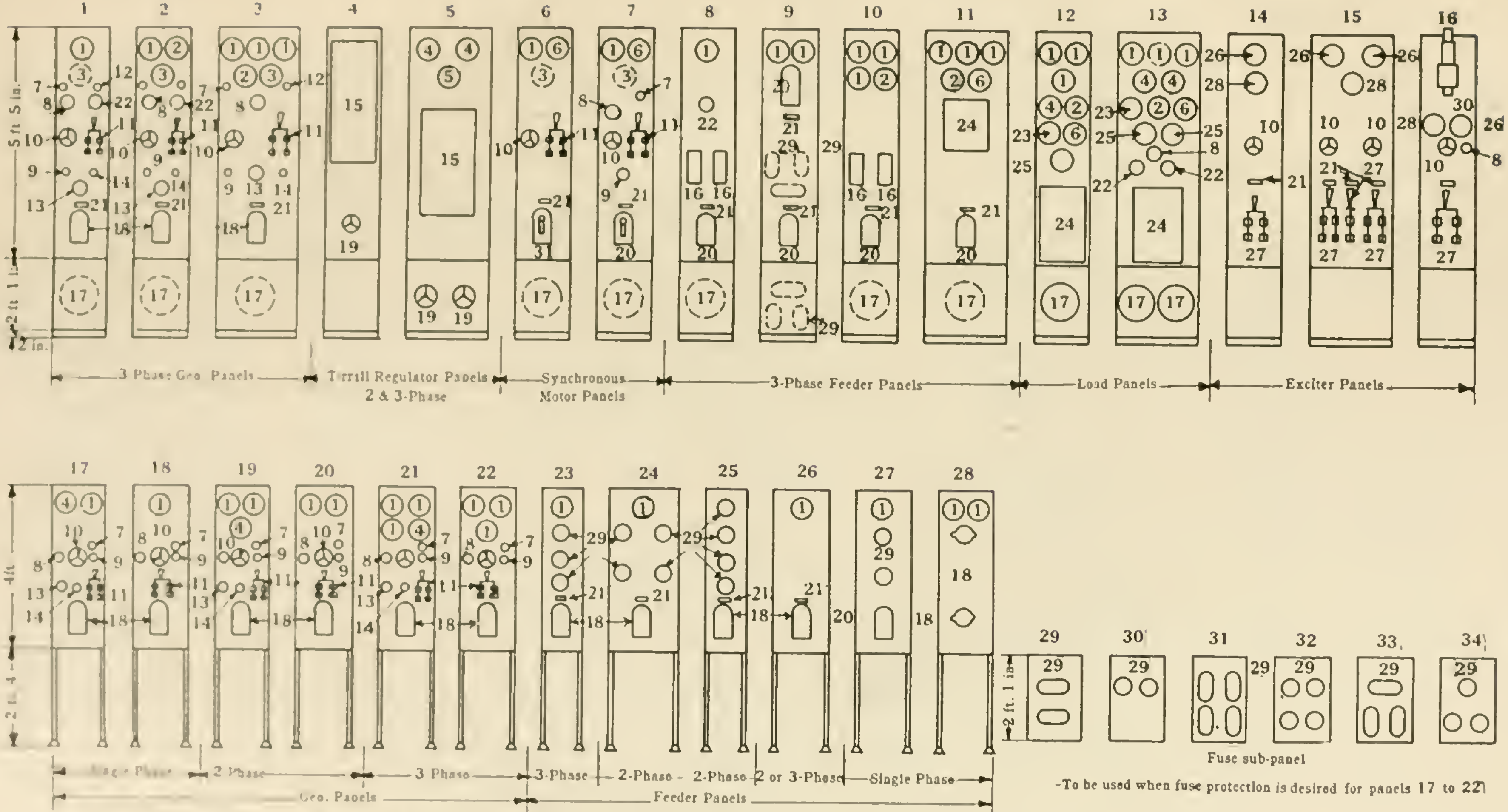

FIG. 6—TYPICAL PANEL ARRANGEMENTS FOR SELF-CONTAINED SWITCHBOARDS

The instruments on the panels are designated by numbers as given in the table below.

1—Alternating-current ammeter
2—Indicating wattmeter
3—Field ammeter
4—Alternating-current voltmeter
5—Synchroscope
6—Power-factor meter
7—Synchronizing lamp
8—Voltmeter receptacle
9—Synchronizing receptacle
10—Rheostat
11—Field discharge switch
12—Ground detector lamp
13—Ground detector receptacle
14—Ground detector push
15—Tirrill regulator
16—Single-phase relay
17—Recording watthour meter
18—Non-automatic oil switch
19—Equalizer rheostat
20—Automatic oil circuit breaker
21—Card holder
22—Ammeter receptacle
23—Frequency meter
24—Graphic recording wattmeter
25—Static ground detector
26—Direct-current ammeter
27—Knife switch
28—Direct-current voltmeter
29—Fuse block (enclosed fuses)
30—Carbon breaker (shunt trip and reverse current relay)
31—Auto-starter switch

wherein the circuits are more carefully protected but provided with few meters, as in Figs. 5, 7, 8, and 9.

3—For the larger plants where the best of circuit-breakers are required, and where a full complement of instruments is necessary, as in Fig. 10.

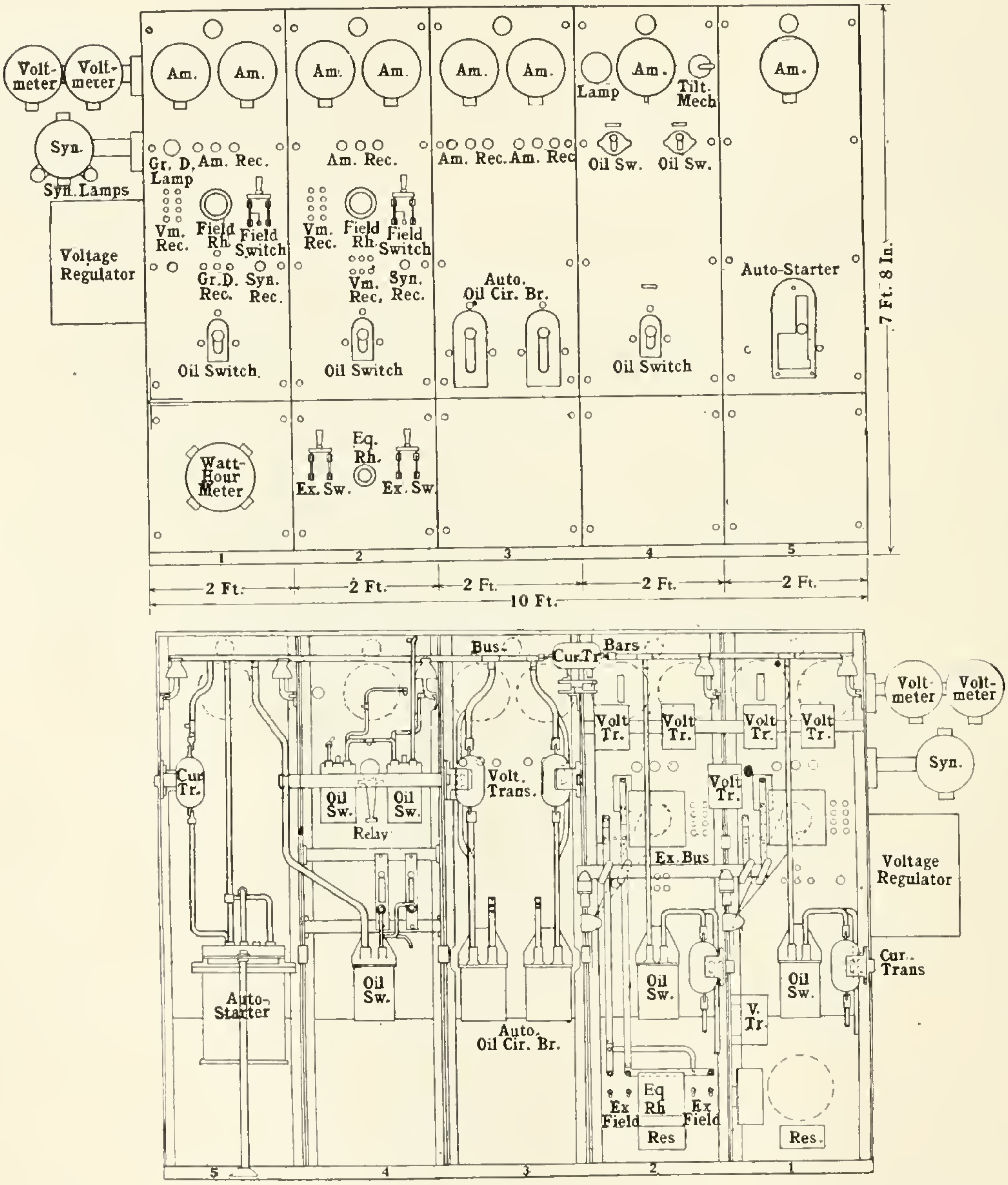

FIG. 7—FRONT AND REAR VIEW DRAWINGS OF SWITCHBOARD, SHOWN IN FIG. 5
Showing the details of arrangement and location of apparatus.

The choice of apparatus, and therefore the design of the switchboard, depends on the size and disposition of the output. The grade of intelligence of the attendants may also have considerable influence. The magnitude of the output determines to a very considerable extent the type of switching devices to be used.

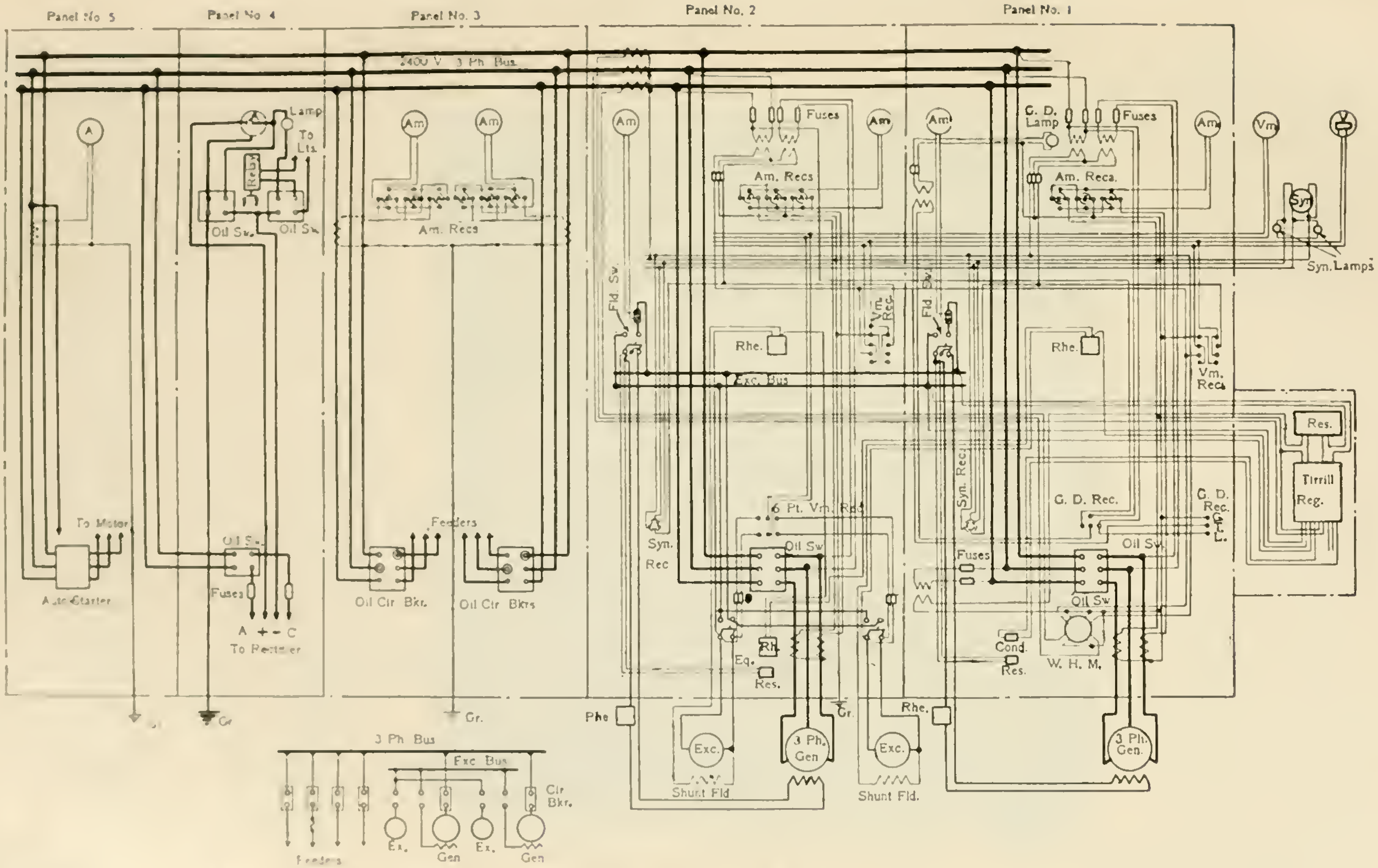

FIG. 8—DETAIL DIAGRAM OF CONNECTIONS OF SWITCHBOARD SHOWN IN FIGS 5 AND 7

View from the rear of board. All apparatus is shown as nearly as possible in its relative location. A single line diagram of the board is shown in the lower left hand corner.

The smaller capacity circuit breakers for 2 200, 3 300 and 4 400 volt service usually have an ultimate breaking capacity* of approximately 2 500 k.v.a. The type of circuit breaker chosen must be capable of opening the maximum output of the station. For example, if the generating units consist of three 800 k.v.a. machines, the circuit breakers must have an ultimate breaking capacity of at least 2 400 k.v.a., when set for instantaneous tripping.

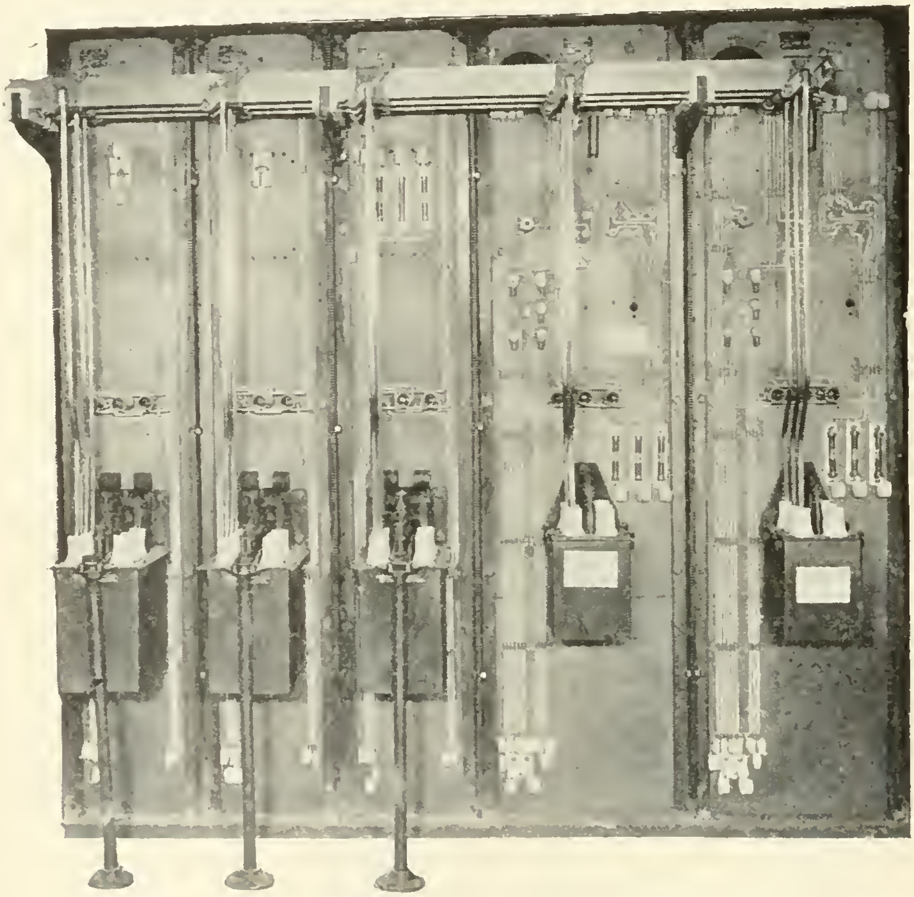

FIG. 9—REAR OF A MEDIUM SIZED BOARD
Showing main and small wiring and bus-bars in place. Absence of instrument transformers and other details gives simple and pleasing appearance.

The selection of non-automatic oil circuit breakers and oil switches is not influenced in this way by the capacity of the station, except as they will be called upon under extreme conditions to open the circuit. They should never be required to open the circuit on an overload or even on a normal load, except where absolutely necessary to save some more valuable piece of apparatus. Their principal function is that of main disconnecting switch. They permit quicker and safer closing or opening of the circuits, than could be accomplished by the usual lever type disconnecting switches. They are therefore commonly used between generators and bus-bars, where automatic action is undesirable, but where quick manual operation is necessary, as during synchronizing. If it is desired that the non-automatic breakers be suitable for clearing any abnormal condition which is not taken care of by the automatic breakers, it is usually safe to assume that, when opened by hand, their ultimate breaking capacity is approximately double that for the same switch or circuit breaker equipped for instantaneous automatic action. This may, under certain conditions, such as gas-engine driven units or slow-speed types, be increased to as much as four

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*By ultimate breaking capacity is now commonly meant the maximum k.v.a capacity which a circuit-breaker will successfully open on short-circuit. By maximum k.v.a capacity is here meant the maximum normal rating, and not the instantaneous capacity on short-circuit which may be many times greater. The true ultimate breaking capacity of a breaker is best expressed by a statement giving the actual number of volt-amperes which it will successfully open, as this statement is independent of reactance in circuit, speed of generator, method of relaying breaker and other modifying conditions.

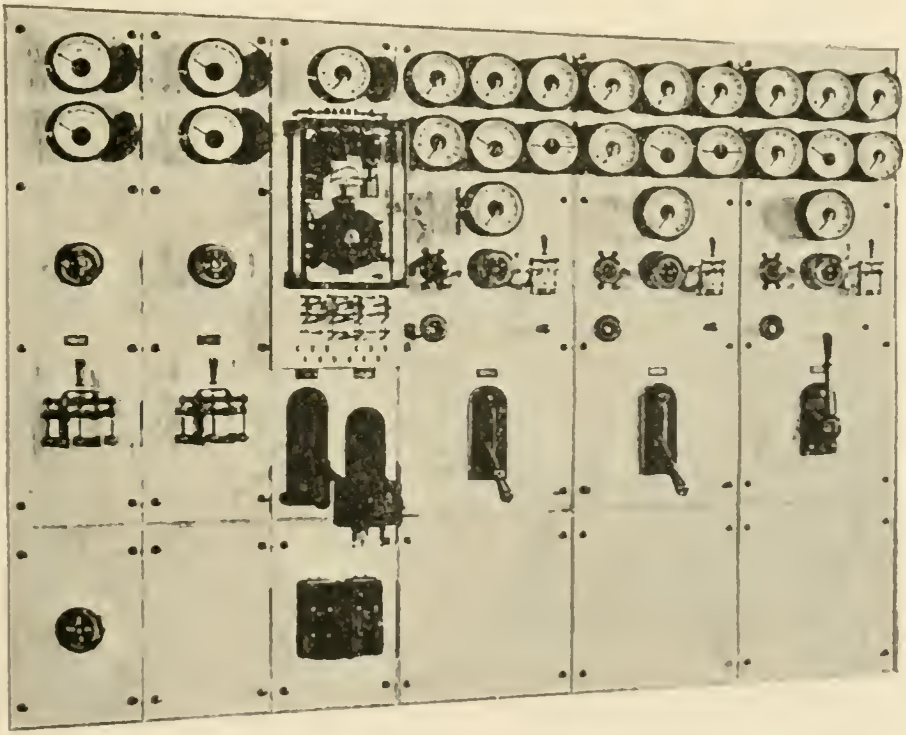


FIG. 10—LARGE CAPACITY SWITCHBOARD (FEEDERS NOT SHOWN), HAVING A FULL COMPLEMENT OF INSTRUMENTS

The panels shown control two exciters, a synchronous motor for one of the exciters, Tirrill regulator, two 300 ampere and one 600 ampere alternating current, three-phase generators. Each generator panel has three ammeters, power-factor meter, alternating-current voltmeter, indicating wattmeter and field ammeter.

times normal breaking capacity. If, however, the conditions are such that the maximum current on short-circuit may be sustained longer than the time required to manually operate the breaker, the ultimate breaking capacity should be the same for non-automatic as for instantaneous operation. The principal limiting factor is the amount of current which will flow on short-circuit. The maximum condition is probably reached when the generating units are turbo-generators, which are capable of delivering many times normal current on short-circuit.

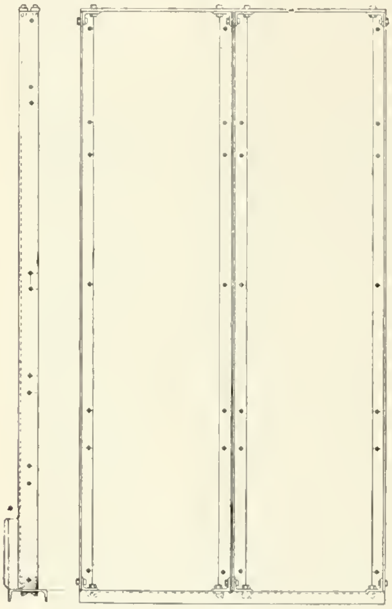


FIG. 11—ANGLE FRAME FOR SWITCHBOARD 90 INCHES HIGH

Made from standard 3x2x¼ in. angle-iron with corner angles of the same shape, with two wrought iron straps ½x1 3/8 in. and with 6 in. channel base weighing 8 pounds per foot.

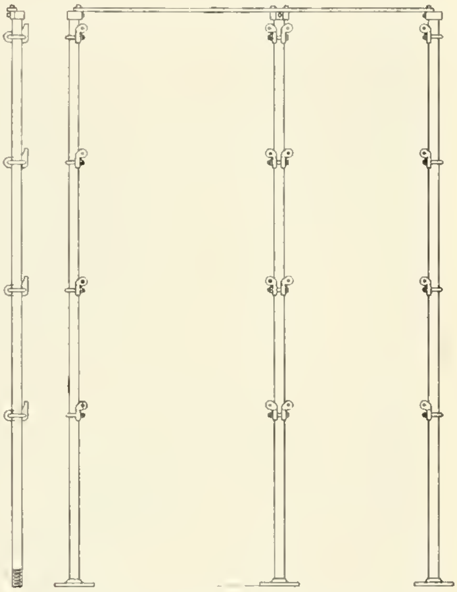


FIG. 12—PIPE FRAME FOR SWITCHBOARD 90 INCHES HIGH

Made from 1¼ in. wrought iron pipe with one wrought iron top strap ½x1 3/8 in. and with cast-iron foot nuts and panel supports.

The better class of automatic circuit breakers designed for switchboard mounting should be capable, on instantaneous operation, of opening 5 000 to 12 500 k.v.a. The high capacity circuit breakers usually have a separate tank for each pole, with the trip coils, which are actuated from series transformers, mounted outside the tanks. The cheaper class of circuit breakers usually have series trip coils, that is, coils through which the entire current of the circuit must pass, and a single tank containing all the poles and sometimes the trip coils. It should be remembered that the ultimate breaking capacity of a circuit breaker is usually doubled by providing it with a definite time limit of two seconds or more. The oscillograph shows that the abnormal conditions caused by a short circuit are usually maintained for not more than one and one-half seconds, the current usually dropping in this length of time to approximately twice normal.

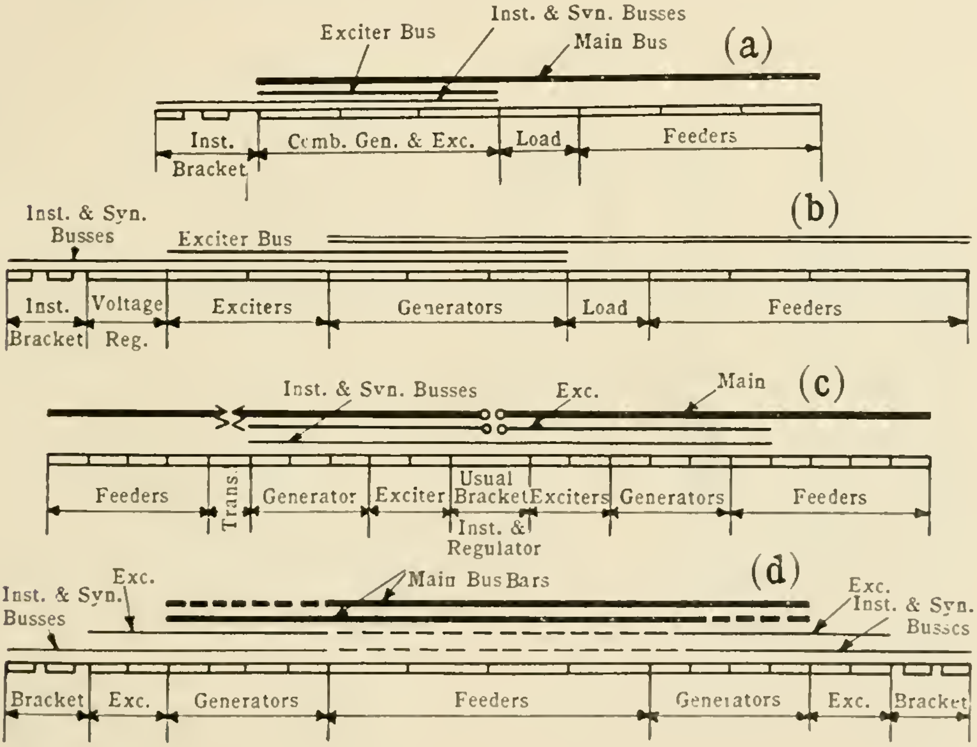


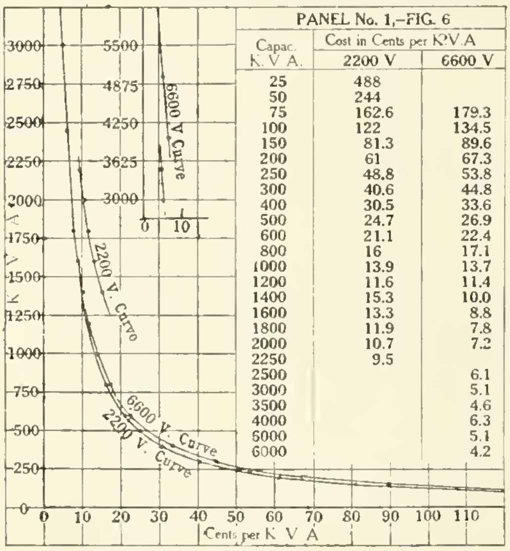
FIG. 13—USUAL ARRANGEMENT OF PANELS AND BUS-BAR SYSTEMS FOR SWITCHBOARD PANELS

In the arrangement shown at *c* the station load consists of two parts, lighting and power. A tie switch is provided to permit parallel operation of the two halves of the station when desirable. The feeder panels are placed at the extreme ends of the board to permit addition to feeders without disturbing the rest of the board, lighting feeders being taken out at one end and power feeders at the other. The switchboard and exciters are located in the center of the station with the alternating-current generators symmetrically arranged on either side.

The arrangement shown at *d* consists of double-throw feeder circuits and single-throw generator circuits. This system may be desirable because of the difficulty of parallel operation where one set of generators differs in characteristics from the other; because of different voltages on the two bus-bars; or because one is alternating and the other direct current. Dotted lines in the main bus-bar indicate an arrangement for double-throw generator circuits; in the exciter bus-bars indicates that arrangement is made for parallel operation of all exciters; in the instrument and synchroscope bus-bars, indicates that arrangement is made for using either set of instruments for the station as desired.

CHOICE OF PANEL DESIGN

Dimensions—The size of the panel and the design of the frame should be in keeping with the apparatus to be mounted thereon. A small schedule of apparatus of the cheaper type and of small capacity should have a small panel with light framework to balance the design properly. Obviously a large schedule of heavy capacity apparatus would be entirely out of place if mounted on small panels with light framework. Two distinct forms of panels appear prominently among the many special panels which have been used; the 90-inch panel with two or more sections of panel material covering the entire frame from top to floor, Fig 6 (1 to 16), and the 76-inch panel with one section of panel material 48 inches high with the frame extending uncovered the remainder of the distance to the floor, Fig. 6 (17 to 28). Both forms may be supported by either angle or tubular framework, but the latter form is usually mounted on tubular frame, as the round piping extending below the panel section, with large ornamental foot nuts, presents a more finished appearance.



PANEL No. 1,–FIG. 6		
Capac. K. V. A.	Cost in Cents per K.V.A	
	2200 V	6600 V
25	488	
50	244	
75	162.6	179.3
100	122	134.5
150	81.3	89.6
200	61	67.3
250	48.8	53.8
300	40.6	44.8
400	30.5	33.6
500	24.7	26.9
600	21.1	22.4
800	16	17.1
1000	13.9	13.7
1200	11.6	11.4
1400	15.3	10.0
1600	13.3	8.8
1800	11.9	7.8
2000	10.7	7.2
2250	9.5	
2500		6.1
3000		5.1
3500		4.6
4000		6.3
6000		5.1
6000		4.2

FIG. 14—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANEL NO. 1, FIG. 6*

Switchboards for two-phase 2 200 volts would cost 2.5 percent higher than the corresponding three-phase boards in capacities from 25 to 800 k.v.a., 4.3 percent higher in capacities from 1 000 to 1 200 k.v.a. and 10 percent higher from 1 400 to 2 250 k.v.a.; for 6 600 volts the two-phase boards will cost 2.25 percent higher from 75 to 3 500 k.v.a. and 10 percent higher from 4 000 to 6 000 k.v.a.

Panel Sections—The determination of the proper number of sections per panel may be influenced by design and arrangement of apparatus, the appearance, strength of the material, and facility in erecting and interchanging. A wide range of selection is presented by the standard lines carried in stock by the manufacturers, and wherever possible some standard size should be chosen. These sizes usually permit the best arrangement and are the result of years of experience. Their choice will enable manufacturers to quote their minimum price and delivery. This is even more true when additions or modifications to an existing marble switchboard are to be made, for while the large stocks of polished marble carried by the manufacturers enable them to match an existing board closely, special sizes must be ordered direct from the quarries where the selection must be made from unpolished marble of shade and markings, as is being quarried at the time of the order

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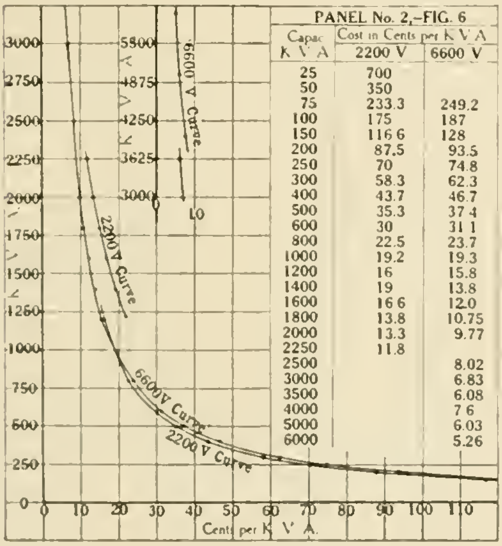
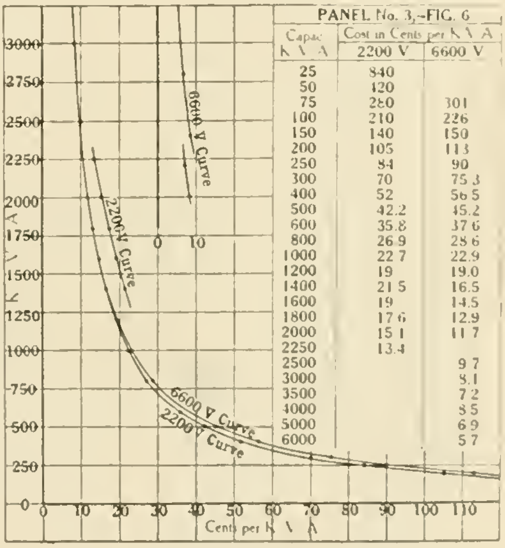
*When combining panels to make up the cost of a complete board, from this and the succeeding curves, the bus-bars should be calculated separately and a sufficient increase should be made in the cost of the boards if the bus-bar capacity at any panel exceeds the capacity of the panel.



PANEL No. 2,–FIG. 6		
Capac K V A	Cost in Cents per K V A	
	2200 V	6600 V
25	700	
50	350	
75	233.3	249.2
100	175	187
150	116.6	128
200	87.5	93.5
250	70	74.8
300	58.3	62.3
400	43.7	46.7
500	35.3	37.4
600	30	31.1
800	22.5	23.7
1000	19.2	19.3
1200	16	15.8
1400	19	13.8
1600	16.6	12.0
1800	13.8	10.75
2000	13.3	9.77
2250	11.8	
2500		8.02
3000		6.83
3500		6.08
4000		7.6
5000		6.03
6000		5.26

FIG. 15—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANEL NO. 2, FIG. 6

Switchboards for two-phase 2 200 volts would cost 1.75 percent higher than the corresponding three-phase boards in capacities from 25 to 800 k.v.a., 3.25 percent higher in capacities from 1 000 to 1 200 k.v.a. and 10 percent higher from 1 400 to 2 250 k.v.a.; for 6 600 volts the two-phase boards will cost 1.5 percent higher from 75 to 3 500 k.v.a., 2.8 percent higher at 4 000 k.v.a. and 5 percent higher from 5 000 to 6 000 k.v.a.



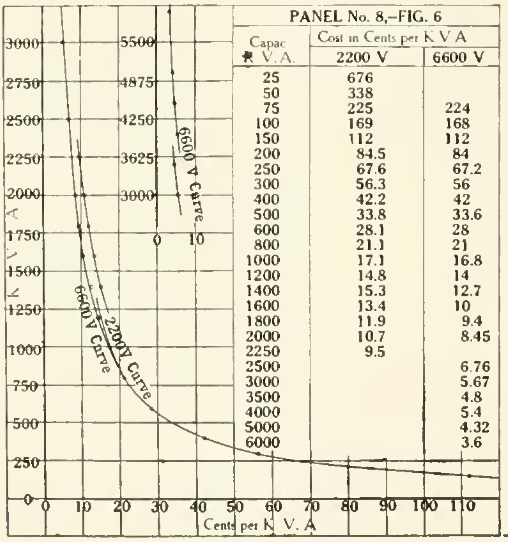
PANEL No. 3,–FIG. 6		
Capac K V A	Cost in Cents per K V A	
	2200 V	6600 V
25	840	
50	420	
75	280	301
100	210	226
150	140	150
200	105	113
250	84	90
300	70	75.3
400	52	56.5
500	42.2	45.2
600	35.8	37.6
800	26.9	28.6
1000	22.7	22.9
1200	19	19.0
1400	21.5	16.5
1600	19	14.5
1800	17.6	12.9
2000	15.1	11.7
2250	13.4	
2500		9.7
3000		8.1
3500		7.2
4000		8.5
5000		6.9
6000		5.7

FIG. 16—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANEL NO. 3, FIG. 6

Switchboards for two-phase 2 200 volts would cost 6.6 percent lower than the corresponding three-phase boards in capacities from 25 to 1 200 k.v.a. and 1.6 percent higher from 1 200 to 2 250 k.v.a.; for 6 600 volts the two-phase boards will cost 6 percent lower from 75 to 3 500 k.v.a. and 3 percent higher from 4 000 to 6 000 k.v.a. The two-phase requires but two ammeters and therefore a 16 in. panel may be used, making the total price lower for two-phase up to 1 200 k.v.a. at 2 200 volts and 3 500 k.v.a. at 6 600 volts when the change to the 600 ampere switch increases the price to a value higher than that for the corresponding three-phase panel.

The usual arrangement for 90-inch panels consists of a 60 to 70-inch upper section with a 30 to 20-inch lower section. Of these the combination of 65 and 25-inch sections and 62 and 28-inch sections are most used. The usual combinations for the three section panels are, upper 20 inches, middle 45 inches, lower 25 inches; or upper 31 inches, middle 31 inches, lower 28 inches.

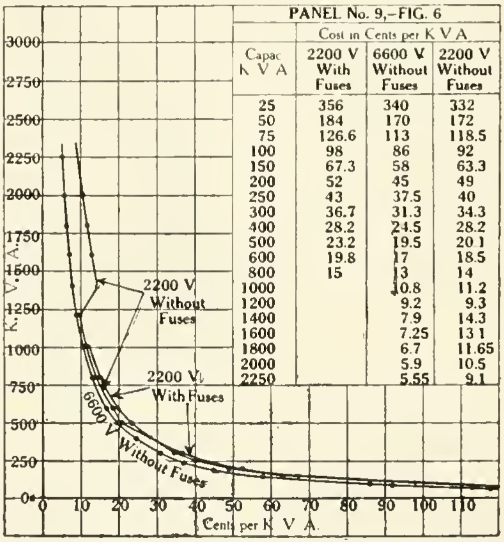
Black marine finished slate is one of the most serviceable materials for this type of board as well as the cheapest. This has a dull velvety black finish which may easily be kept in good condition. The natural material is usually purple slate. When rubbed with oil this finish will not show oil stains. This feature is of special importance where oil circuit breakers are mounted directly on the panels for, in spite of all precautions, the oil will usually get on the panels sooner or later. Natural black slate, the best of which comes from Maine, is used without the application of any artificial finish other than clear oil, and is even more serviceable than the black marine slate, though more expensive.



PANEL No. 8,–FIG. 6		
Capac K. V. A.	Cost in Cents per K V A	
	2200 V	6600 V
25	676	
50	338	
75	225	224
100	169	168
150	112	112
200	84.5	84
250	67.6	67.2
300	56.3	56
400	42.2	42
500	33.8	33.6
600	28.1	28
800	21.1	21
1000	17.1	16.8
1200	14.8	14
1400	15.3	12.7
1600	13.4	10
1800	11.9	9.4
2000	10.7	8.45
2250	9.5	
2500		6.76
3000		5.67
3500		4.8
4000		5.4
5000		4.32
6000		3.6

FIG. 17—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANEL NO. 8, FIG. 6

Switchboards for two-phase 2 200 volts would cost 15 percent higher than the corresponding three-phase boards in capacities from 25 to 1 200 k.v.a. and 13 percent higher from 1 400 to 2 250 k.v.a.; for 6 600 volts the two-phase boards will cost 16 percent higher from 75 to 3 500 k.v.a. and 13 percent higher from 4 000 to 6 000 k.v.a.



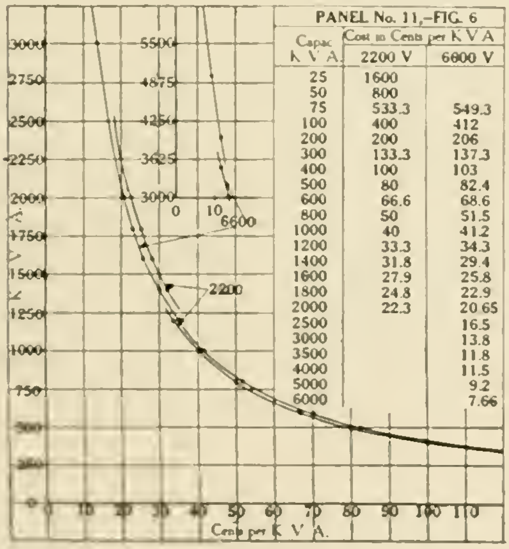
PANEL No. 9,–FIG. 6			
	Cost in Cents per K V A		
Capac K V A	2200 V With Fuses	6600 V Without Fuses	2200 V Without Fuses
25	356	340	332
50	184	170	172
75	126.6	113	118.5
100	98	86	92
150	67.3	58	63.3
200	52	45	49
250	43	37.5	40
300	36.7	31.3	34.3
400	28.2	24.5	28.2
500	23.2	19.5	20.1
600	19.8	17	18.5
800	15	13	14
1000		10.8	11.2
1200		9.2	9.3
1400		7.9	14.3
1600		7.25	13.1
1800		6.7	11.65
2000		5.9	10.5
2250		5.55	9.1

FIG. 18—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANEL NO. 9, FIG. 6

The two-phase panels of this type cost approximately 2.3 percent more than the corresponding three-phase panels.

Black marine finish is often applied to marble, especially when the voltage of the live parts mounted thereon is too great to permit the use of slate. Thus whole switchboards, or only certain high voltage sections of slate switchboards, may be made of black marine finished marble. This material is cheaper than the natural polished marble, as no polish is required and the material is usually that rejected from the natural finished marbles on account of blemishes in marking and coloring.

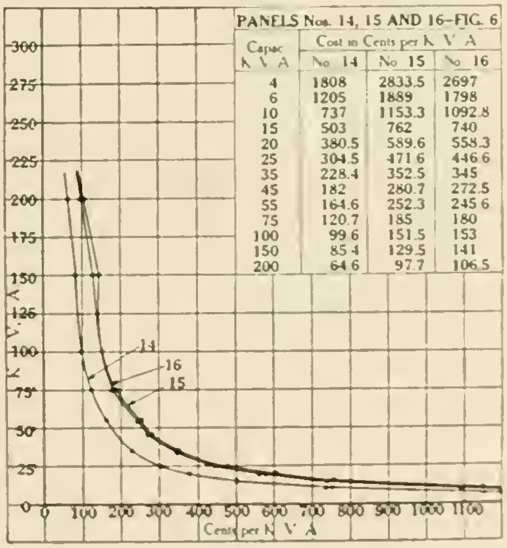
Of the natural finished marble, the blue Vermont is the best domestic marble for switchboard work, owing to its good insulating qualities and its uniformity in coloring and marking. White Italian marble, though possessing better mechanical and electrical properties, is usually prohibitive on account of its cost. Its use is now confined chiefly to those applications in which appearance is a major consideration. All polished marble switchboards for this class of service should have the back and edges, also the sides of all holes, treated with an oil proof varnish, to prevent oil stains from discoloring the marble. The appearance is considerably improved if a clear varnish is used, as the natural marking of the marble is thus brought out almost as well as when polished. Where current carrying parts are mounted directly on the switchboard, slate can seldom be used above 600 volts, whereas marble may be used for voltages as high as 3 300 volts.



PANEL No. 11,–FIG. 6		
Capac K V A	Cost in Cents per K V A	
	2200 V	6600 V
25	1600	
50	800	
75	533.3	549.3
100	400	412
200	200	206
300	133.3	137.3
400	100	103
500	80	82.4
600	66.6	68.6
800	50	51.5
1000	40	41.2
1200	33.3	34.3
1400	31.8	29.4
1600	27.9	25.8
1800	24.8	22.9
2000	22.3	20.65
2500		16.5
3000		13.8
3500		11.8
4000		11.5
5000		9.2
6000		7.66

FIG. 19—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANEL NO. 11, FIG. 6

Prices for two-phase panels are approximately 3.6 percent higher than the corresponding three-phase panels.



PANELS Nos. 14, 15 AND 16–FIG. 6			
Capac K V A	Cost in Cents per K V A		
	No 14	No 15	No 16
4	1808	2833.5	2697
6	1205	1889	1798
10	737	1153.3	1092.8
15	503	762	740
20	380.5	589.6	558.3
25	304.5	471 6	446 6
35	228.4	352.5	345
45	182	280.7	272.5
55	164.6	252.3	245 6
75	120.7	185	180
100	99 6	151.5	153
150	85 4	129.5	141
200	64 6	97.7	106.5

FIG. 20—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANELS NO. 14, 15 AND 16, FIG. 6

For the small boards the tubular frame is undoubtedly the best selection. The lower part of these frames which appears between the panel section and the floor does not require any special covering to give a finished appearance. The number of castings, bolts, etc., is small, as these panels usually have but four mounting bolts, and therefore assembly at the factory, shipment, erection and alterations or additions are easily accomplished. The frame for multi-section panels, however, presents a different problem. The comparison between the 2 × 3 × ¼-inch angle frame (Fig. 11) and the 1¼-inch tubular frame (Fig. 12) is about as follows:

Cost of frame, Materials for Shipment	Tubular frame approximately 25 percent cheaper.
Cost of Packing Painted and Assembled	Angle frame approximately 65 percent cheaper.
Cost of Erecting at Destination	Angle frame approximately 50 percent cheaper.
Mechanical Strength and Alignment of Panels	Greatly in favor of angle frame.

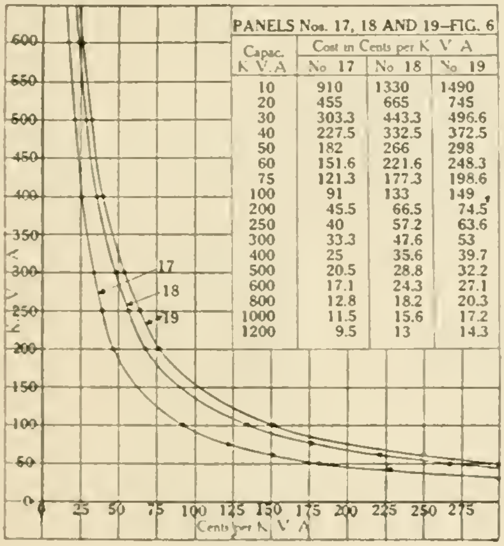
Where angle frames are employed, the panel sections and the two panel uprights form a unit, and may be handled as such in shipping and erecting. As there is no necessity for removing the panel sections from the angle frame before shipment, the panels may be completely wired by the manufacturer before delivery. For the tubular frame, however, one upright is common to two adjacent panels and to pack the panel as a whole, a temporary upright must be supplied with each panel but one. This renders the packing and erecting at destination so much more difficult, to say nothing of the added expense of the temporary uprights, that the tubular frame switchboards are usually shipped unassembled.

ARRANGEMENT OF PANELS

A great number of arrangements of the panels of a switchboard may be made, each possibly with distinctive merits of its own. It is obvious, however, that as there are so many switchboards quite similar in design, as well as in the functions which they perform, there must be some logical arrangement which, in general, meets almost every requirement. Such an arrangement, as shown in Fig. 13(a), is as follows: Tirrill regulator panel (if any) at one end of board followed by exciter panels, generator, totalizing, transformer and feeder panels. Some of the advantages of this arrangement over other possible arrangements are:

Ease of adding to the board without materially disturbing the existing panels. By arranging the panels in order of their current capacities, with the heaviest capacity panels at the center of the board, the bus-bar copper is usually reduced to a minimum. The output of the station may be totalized on one set of meters connected to bus-bar transformers, between the generator and the feeder panels. (When the generator panels are separated by feeder panels, totalizing cannot be accomplished without undesirable intricacies in wiring connections.) The alternating-current bus-bars do not cross the exciter panels. The exciter bus-bars are of minimum length. The concentration of various panels of a kind at one part of the board assists the operator materially by reducing the number of steps, and consequently the time required for any switching operation.

The arrangement of panels for each switchboard should, however, be given careful consideration. An arrangement may then be chosen which will suit the local conditions better than the arrangement just described (see Fig. 13(a), (b), (c) and (d). The determining factors to be considered are:

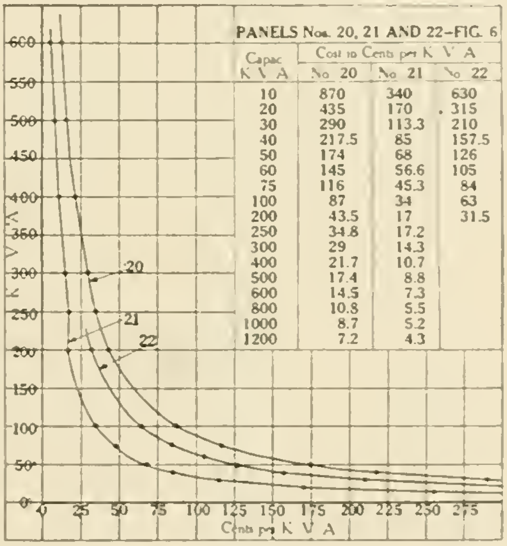


PANELS Nos. 17, 18 AND 19—FIG. 6

Capac. K V.A	Cost in Cents per K V A		
	No 17	No 18	No 19
10	910	1330	1490
20	455	665	745
30	303.3	443.3	496.6
40	227.5	332.5	372.5
50	182	266	298
60	151.6	221.6	248.3
75	121.3	177.3	198.6
100	91	133	149
200	45.5	66.5	74.5
250	40	57.2	63.6
300	33.3	47.6	53
400	25	35.6	39.7
500	20.5	28.8	32.2
600	17.1	24.3	27.1
800	12.8	18.2	20.3
1000	11.5	15.6	17.2
1200	9.5	13	14.3

FIG. 21—COST OF THREE-PHASE SWITCHBOARDS CORRESPONDING TO PANELS NO. 17, 18, AND 19, FIG. 6

Prices for two-phase, 2 200 volt board of the type corresponding to panel 17 will be 0.5 percent higher than the corresponding three-phase panel from 10 to 200 k.v.a. and 6 percent higher from 200 to 1 200 k.v.a.; for panel 18, 0.5 percent higher from 10 to 800 k.v.a. and approximately the same price above 1 000 k.v.a.; for panel 19 approximately 0.5 percent higher throughout. The prices for two-phase and three-phase panels of these types are almost identical owing to the fact that a narrower panel and but two ammeters for two-phase offset the four pole breaker and additional wiring.



PANELS Nos. 20, 21 AND 22—FIG. 6

Capac K V A	Cost in Cents per K V A		
	No 20	No 21	No 22
10	870	340	630
20	435	170	315
30	290	113.3	210
40	217.5	85	157.5
50	174	68	126
60	145	56.6	105
75	116	45.3	84
100	87	34	63
200	43.5	17	31.5
250	34.8	17.2	
300	29	14.3	
400	21.7	10.7	
500	17.4	8.8	
600	14.5	7.3	
800	10.8	5.5	
1000	8.7	5.2	
1200	7.2	4.3	

FIG. 22—COST OF THREE-PHASE SWITCHBOARD CORRESPONDING TO PANELS NO. 20, 21, AND 22, FIG. 6

Prices for a two-phase board of the type corresponding to panel 20, Fig. 6 are approximately 8 percent higher than for the corresponding three-phase panel; for panel 21, 6 percent higher from 10 to 200 k.v.a., and 16 percent higher from 250 to 1 200 k.v.a.; and for panel 22, 11 percent higher.

The scheme of main connections, the scheme of operation, the geography of the station apparatus, the arrangement of cables to and from the switchboard, the desirability of totalizing the load, and future additions.

Less attention is usually given to the arrangement of cables than their importance warrants. It is not unusual to find arrangements which save copper in the bus-bars at the expense of increase in the cost of cable. Later additions are often made at excessive cost and great inconvenience to the operation of the station. Blank panels properly located during the initial installation usually save many times their cost. A carefully prearranged scheme of interchanging panels may, however, permit the making of all necessary additions. For example, the bus-bars, instrument transformer supports and all openings in the floor may be arranged so that they will suitably accommodate future additions.

ARRANGEMENT OF APPARATUS

The usual arrangement of apparatus on individual panels as recommended by best practice is shown in Fig. 6. Some operators prefer arrangements which differ, more or less, from those illustrated, and in some cases the conditions may warrant radical departures, but if the following requirements are complied with, it will usually be seen that the arrangements illustrated are obtained:

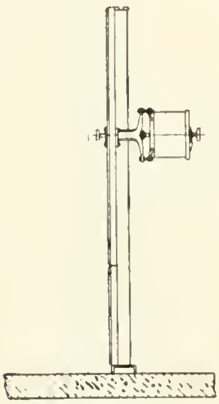


FIG. 23

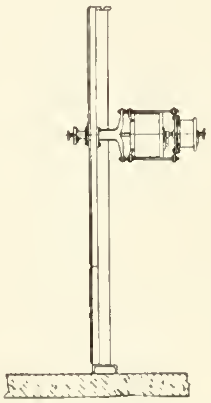


FIG. 24

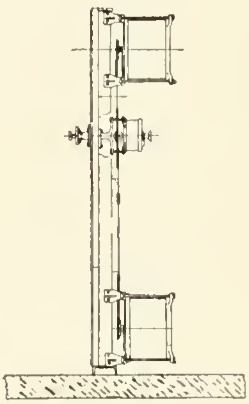


FIG. 25

FIG. 23—SINGLE GENERATOR RHEOSTAT SUPPORTED FROM BACK OF PANEL BY A SINGLE BRACKET

FIG. 24—GENERATOR AND EXCITER RHEOSTAT MOUNTED IN COMBINATION AND SUPPORTED FROM SINGLE BRACKET

FIG. 25—COMBINATION MOUNTING OF HANDWHEELS WITH GENERATOR RHEOSTAT MOUNTED NEAR EITHER TOP OR BOTTOM OF BOARD; EXCITER RHEOSTAT ON SINGLE BRACKET

1—Indicating instruments should be mounted at or a little above the height of the eyes.

2—Meters of a kind (for example, ammeters) should be symetrically grouped on the panel so that phase distinctions are apparent.

3—Meters of a kind should be in alignment with each other on the various panels, for convenience, appearance and symmetry of wiring.

4—Voltmeter receptacles and similar plugging devices should be located as near the instruments as possible to simplify and decrease amount of small wiring.

5—Rheostats, unless very small, should be sprocket operated, the face plates and resistance mounted as a unit and located in some convenient place where the contacts may readily be inspected and where the heat from the resistance will do no harm. The handwheels should be located near the center of the panel at such a height that the operator may readily watch his instruments while adjusting the rheostat and can have one hand free to operate the voltmeter receptacle, field switch or main switch.

6—The main switches or circuit-breakers should be located at a height most convenient for ease in operation. They must not be so close to the edge of the panel section as to interfere with the frame work or to give insufficient distance to the adjacent apparatus, or so near the floor as to prevent free removal of the tanks for inspection.

7—Watthour meters or relays may be mounted on the subsections or at the rear of the board, as they require only occasional attention.

8—High tension bus-bars should be mounted near the top of the board to avoid accidental contact, thus obviating the necessity of insulating them to prevent injury to attendants. This arrangement also permits free access to the rear of the board.

9—Voltage and current transformers may be mounted at the rear of the board on suitable supports, but usually at the expense of accessibility to the instrument wiring and auxiliaries mounted on the back of the panel, and of the general appearance of the installation. It is recommended that they be placed apart from the board wherever possible, (See Fig. 9); beneath the floor if the leads go down, or on the wall where they go up.

10—Such instruments as graphic recording meters, static ground detectors and Tirrill regulators should not be placed on swinging brackets or swinging panels.

COSTS

The following curves with tables, Figs. 14 to 22 inclusive, showing the cost in cents per kilovolt-ampere capacity, will indicate the relative costs of the various panel arrangements and of the comparative cost of 2 200 and 6 600 volt panels. The figures given include all wiring details, and bus-bars of the rated capacity of the panels. The tables permit a more accurate interpretation of the curves and also indicate the values beyond those shown by the curves. The irregularities and breaks in the curves are occasioned by the fact that two sizes of oil switch are involved, namely the 300 and 600 ampere capacities. The change in capacity for this rating comes between 1 200 and 1 400 kw. for 2 200 volt panels, and between 3 000 and 4 000 kw. capacity for 6 600 volts. As shown by the curves the prices of the generator panels are usually the same, regardless of k.v.a. capacity, up to 500 or 800 k.v.a. Above these capacities they increase by steps owing to additional cost of series transformers, panel wiring, etc., until the sudden change to the higher capacity switch causes a break in the curve. The two-phase panels usually exceed the three-phase panels in cost by the cost of the extra circuit breaker pole and its wiring, but this is not true where three ammeters are used for three phases and two for two phases, as the fewer meters and the narrower panel may make the two-phase cheaper than the three-phase panel.

REAR OF BOARD

The design of the rear of a switchboard is a good indication of its real worth as an engineering production. Even more care is necessary than for the front, as it is here that switchboard troubles most usually occur, and the chance of their occurrence is multiplied if a careless or an inconsistent design is adopted. It is a comparatively simple matter to produce a well-arranged, well-appearing front, but the rear of the board with its many details, forming a combination of high and low voltage conductors, moving mechanical parts, instrument and control wiring, oil circuit breakers, rheostats, etc., persents a problem which requires originality and systematic design on the part of the engineer and a skilled and patient draughtsman. This is probably more true of the self-contained switchboard than of any other, as the greater part, if not all, of the auxiliary apparatus is mounted upon or supported from the rear of the board. This auxiliary apparatus consists chiefly of bus-bars, instrument wiring, instrument transformers, fuse blocks and fuses, main interconnections with their supports, instrument and discharge resistances and rheostats, but very often it is necessary that space be found for disconnecting switches, fuses for main circuits, wattmeters and relays. This is obviously bad engineering and should be avoided by finding room for much of the high voltage apparatus, such as instrument transformers, disconnecting switches and fuses away from the board itself (Fig. 9). This treatment permits an accessible, open arrangement of the main and control wiring and other apparatus which should naturally be mounted on the back of the panels.

Rheostats, when small, are best located at the rear of the board, preferably supported on brackets which will not materially decrease the space required for instrument wiring and other details, Fig. 23. When individual exciters are used with the generators their rheostats may be mounted in combination, the handwheels being concentric on the front of the panel, the main rheostat being controlled by means of a hollow shaft which contains the shaft of the exciter rheostat, Fig. 24.

Where the size of the rheostats precludes the combination mounting, the concentric handwheels may still be retained by making the main rheostat sprocket operated, and locating it near the top or bottom of the panel, Fig. 25. The larger capacity rheostats, whose resistance must be made up of cast iron grids, should be mounted entirely independent of the board, Fig. 26. It is not good practice to mount the face plate at the board and the resistance apart from it because of the great number of cables required to connect one to the other, a 48-step face plate, for example, requiring 49 leads. The better method is to mount the face plate as indicated in Figs. 28 and 29.

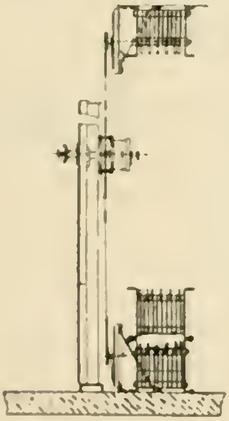


FIG. 26

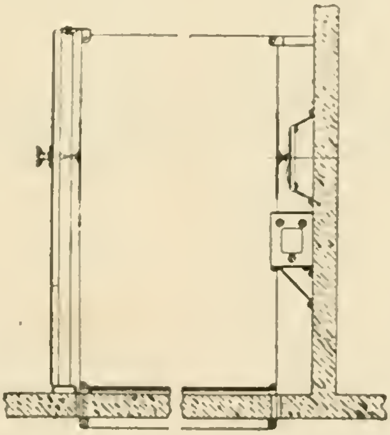


FIG. 27

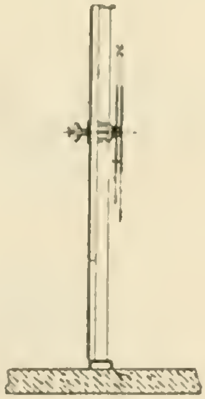


FIG. 28

FIG. 26—SAME AS FIG. 25 EXCEPT GENERATOR RHEOSTAT IS MOUNTED ON THE FLOOR OR SUPPORTED FROM THE CEILING
FIG. 27— REMOTE CONTROL WALL MOUNTING OF LARGE GENERATOR RHEOSTAT SHOWING THREE GOOD METHODS OF ARRANGING THE CONTROL
FIG. 28—HANDWHEEL OF GENERATOR AND EXCITER RHEOSTAT MOUNTED IN COMBINATION; BOTH RHEOSTATS REMOTE CONTROLLED

Cables to and from the switchboard should be supported in such a manner that their weight will not be suspended from a soldered joint or the terminal of a circuit breaker. Cables should not be used as connections for switchboard apparatus where bends are necessitated, as they will not keep their form unless carefully supported or enclosed in a stiff covering. Connections are preferably made of flame-proof solid wire, well insulated against accidental contact. If the connection is of too large capacity to be made with one 0000 wire, and it is inadvisable to use two or more, bare copper rods, tubes or straps should be used. This should be well insulated after erection with varnished cambric tape or its equivalent, to protect against accidental contact, and it is advisable to flame proof all such insulation with asbestos tape or some equivalent. To give it permanency the asbetos tape should be treated with a binding solution such as silicate of soda. As practically all switchboard mounted circuit breakers are now designed with their terminals entirely enclosed in a removable micarta, or other insulating tube, the connection to the circuit breaker must rise vertically the height of this tube to permit access to the terminals.

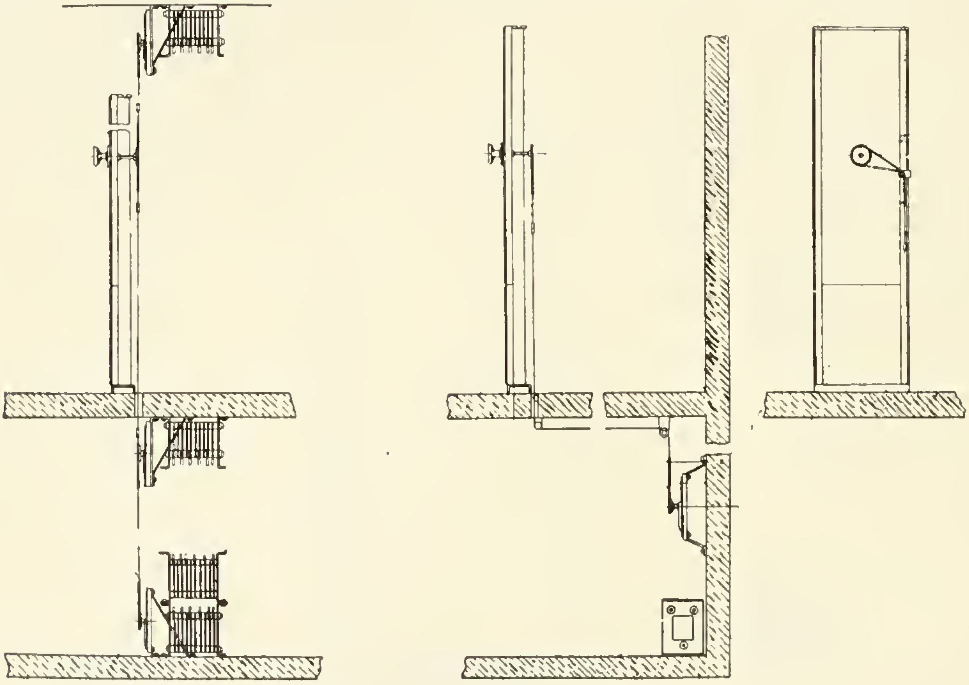


FIG. 29—SUGGESTED ARRANGEMENTS FOR LARGE REMOTE CONTROLLED RHEOSTATS

All connections, both main and auxiliary, should, when at all possible, be run vertically and horizontally with right angle bends made to a sufficient radius, so that the conductor will not be injured. The same suggestion applies to any straps, brackets, braces or other members of the switchboard construction, for the appearance of the board is very greatly increased thereby. This rule is of further advantage in producing a uniform spacing throughout if properly executed, whereas any other method will result in many of the conductors being much closer together at some places than at others. This results either in the loss of the factor of safety in insulating distance, or an increase in the depth of the entire arrangement.

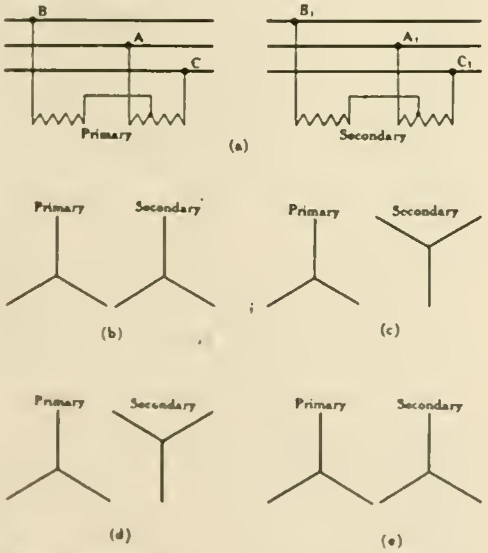
THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

816—T-Connection of Transformers—Please .explain the "T" transformer connection and show a diagram. J.D.N. (ORE.)

Two transformers "T"-connected may be used to transform three-phase current. One end of the primary winding of one transformer is connected to the middle point of the primary winding of the other transformer. The secondary of the first transformer is likewise connected to the middle of the secondary of the second transformer. With a three-phase e.m.f. impressed on the three primary terminals, a three-phase e.m.f. will be induced at the three secondary terminals. If both transformers are of the same "polarity" the primary and secondary windings of the two transformers must be similarly connected. If the transformers are of unlike polarity the secondary of the first or "teaser" transformer must be reversely connected from the primary; otherwise phase transformation will take place in the second transformer accompanied by poor regulation. Fig. 816 (a) shows normal primary and secondary connection. Figs. 816 (b) and (c) show current relations in normal connections of "negative" and "positive" polarity windings, the letters indicating the direction of flow of the current represented by the vector. Figs 816 (d) and (e) show the effect of reversing the secondary connection of the teaser, resulting in the vector representing current in corresponding portions of primary and secondary windings being out of phase. For explanation of "polarity of transformer" see article on "Effect of Electrostatic Stresses and Ground Connections on Transformer Insulation" in series on "Continuity of Service," Mar. 1911, p. 266. C.F.



Figs. 816 (a), (b), (c), (d), and (e)

(a)—Connections of primary and secondary.
(b)—Current relations in T-connected transformers of "positive" polarity.
(c)—Current relations in T-connected transformers of "negative" polarity.
(d)—Current relations in T-connected transformers of "positive polarity, with "teaser secondary reversed.
(e)—Current relations in T-connected transformers of "negative" polarity, with "teaser" secondary reversed.

817—Phasing Out Three-Phase Transformers for Parallel Operation with Single-Phase Unit—We have recently purchased a 500 kw, three-phase, delta to delta, 10 000 to 575 volts, oil cooled transformer. This unit will run a three-phase induction motor. We have phased in and run it with a generator, but can not phase it in with our banks of oil cooled transformers, of which we have 3 600 kw capacity in banks of 900 kw each, delta to delta 10 000 to 575 volts. We have tried various combinations of connections for secondary phase relations, but could find only two zero voltages. We found some combinations that gave 575 volts and others that gave 1 150 volts. Please suggest cause and remedy, and give sketch showing vector relations, etc. C.A.T. (MASS.)

The bank of three single-phase transformers can be phased out with the three-phase transformer as follows:—Connect the three-phase transformer and the three single phase units in parallel on the high-tension side as shown in Fig. 817 (a), and apply voltage to it. Then, to parallel on the low-tension side, each single phase transformer should be phased out separately with the three-phase unit. To do this, connect terminal *4* of single-phase transformer No. 1 to terminal *1* of the three-phase unit and measure the voltage between terminals *2* and *5*. If the voltage is zero the connection is correct and terminal *1* should be connected permanently to *4*, and *2* permanently to *5*. If the voltage is 1 150, the phases correspond, and the connections are reversed, and hence *4* should be connected to *2*, and the voltage between *1* and *5* will then be zero. Permanent connections should therefore be made accordingly. If, however, when *1* is connected to *4* the voltage between *2* and *5* is found to be 575 or 995, then *4* and *5* do not belong in the same phase with *1* and *2*. If this is the case, then with *1* and *4* connected together, measure the voltage between *3* and *5*. If it is zero, the connection is correct and it should be joined to *4* and likewise *3* permanently to *5*. If it is 1 150, the phases correspond but the connections are reversed, so that *1* should be joined to *5* and *4* to *3*, permanently. If, however, with *1* joined to *4*, the voltage between *3* and *5* should measure 575 or 995, then *1* and *3* do not belong in the same phase with *4* and *5*. It is then evident that, since *4* and *5* are not in phase with *1* and *2* or *1* and *3*, they must be in phase with *2* and *3*. Then, connect *2* to *4* and measure the voltage between *3* and *5*. If it is zero, then *2* should be connected to *4* and *3* to *5*, permanently. If it is 1 150, the phases correspond but the connections are reversed, so that *2* should be connected to *5* and *3* to *4*, permanently. In a similar manner, terminals *6* and *7* of transformers *2*, and terminals *8* and *9* of transformer *3* should be phased out. From a study of the above instructions the following will be noted: 1—The possible voltages to be measured are: zero, 575, 975 and 1 150. 2—Zero voltage indicates the right phase and the correct connections. 3—A measured voltage of 1 150 indicates the right phase but reversed connection. 4—The measured voltages of 575 or 995 indicate the wrong phase. The phase relations for the four different voltages named above are shown in diagrams 769 (b), (c), (d) and (e). If a three-phase transformer having a ratio of 10 000 to 575 volts is connected in star on the high-tension side and in delta on the low-tension side, it will be impossible to parallel it with a bank of three single-phase transformers having a ratio of 10 000 to 575 volts. Note especially No. 554, June, 1911; also Nos. 553, June, 1911; 491, Oct., 1910; 256, May, 1909 and 157, Oct., 1908. W.N.M.

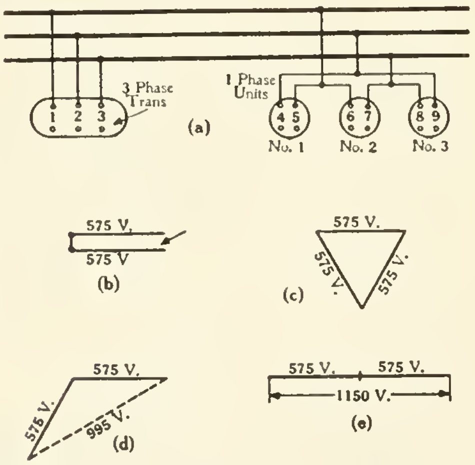


Fig. 817 (a), (b), (c), (d), and (e)

818—Connection of Transformer Coils in Series—Parallel—Several single-phase transformers with a ratio of 22 500 to 5 350 volts are being used on a 22 500 volt, three-phase line with the primaries connected in delta and the secondaries connected in star. There are eight primary coils and four secondary coils in each unit. Three of these secondary coils have 83 turns per coil, while the fourth has 68 turns with an additional 15 turns separated therefrom to be used for regulating purposes. The units were made for operation with the secondary coils all in series but for our service requirements it was necessary to connect the coils in series parallel. However, the additional 15 turns were not used. In some of the units two of the four coils were connected in parallel and then connected in series with the other two coils in parallel. In other of the units two of the coils in series were paralleled at the outer ends with the two remaining coils connected in series. Our experience was that the transformers which were paralleled as per the first arrangement operated satisfactorily, whereas the units in which the coils were operated according to the second arrangement heated up and burnt out. Will you please explain the difference in operation? C.M. (CAL.)

The developments of the different transformer connections are shown by Figs. 818 (a) and (b). In either case there was a resultant voltage equivalent to the voltage of 15 turns causing circulating current. For Fig. 818 (a) this circulating current was in one-half the winding and opposed by the resistance of 151 turns, while for Fig. 818(b) the current circulated through the entire winding and was opposed by the resistance of 317 turns. Since the resistance opposing the circulting current in Fig. 818 (b) is 2.1 times as great as that in Fig. 818 (a), the circulating current in Fig. 818 (a) was 2.1 times that in Fig. 818 (b). Therefore, the heating and consequently the tendency to burn out is several times greater for Fig. 818 (a) than for Fig. 818 (b). However, there will probably be a burn out in either case in a short time. Fig. 818 (b), *with the 15 turns included* is the standard way of connecting coils in series-parallel. J.F.P.

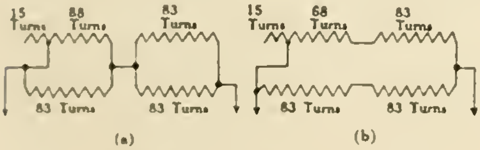


Fig. 818 (a) and (b)

819—Electrolytic **Rectifier**—A chemical converter is required for use with a small motor, small magnets, or for charging batteries. How should the elements be connected together? There are four battery jars, each to contain a crescent shaped aluminum plate and a small lead pole of circular section. What electrolyte should be used for such cells and what should be the approximate dimensions of jar, lead pole and aluminum plate for a 20 ampere outfit? What would be the efficiency of such a rectifier? C.J.B (ILL.)

The arrangement of connections for charging the cells is indicated in Fig. 819 (a). Probably the best electrolyte is a saturated solution of pure neutral ammonium phosphate. The size of the jars depends upon the means for cooling. They should hold at least one quart each, and if used for steady load should be arranged with means of circulating the electrolyte through a cooling radiator. The lead should have a surface area of about 40 square inches. The aluminum should have 40 square inches or more surface area. The efficiency is very low and depends upon the voltage, current, temperature and general design. A cell efficiency of 30 percent for charging (6 volt) ignition batteries should be considered excellent. Within certain limits the efficiency increases with the voltage and decreases rapidly as the temperature of the cell increases. L.W.C.

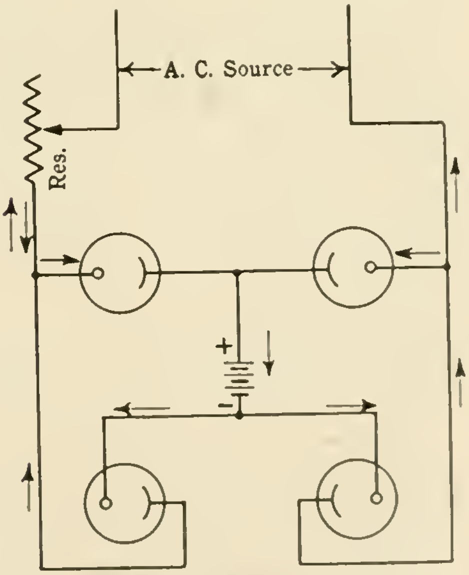


Fig. 819 (a)

820—Voltage and Phase Relations with Special Transformer Connection—In the transformer connection shows in Fig. 820 (a), a two coil, 11 000 volt transformer with a ratio of 1 to 1 is designated as No. 1. One secondary terminal of this transformer is grounded, and this same terminal is also connected at the middle point of an 11 000 to 22 000 volt auto-transformer, designated as No. 2, which is, therefore, also grounded. The primary connections to the 11 000 volt, three-phase, star-connected generator are as indicated. What are the values of the three voltages and their phase relations as measured between *A* and *B*, *A* and *C*, and *B* and *C*? R.E.S. (CONN.)

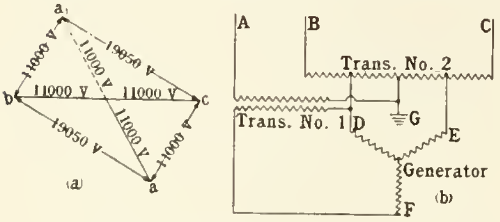


Fig. 820 (a) and (b)

In the vector diagram Fig. 820 (b), let *bc* represent the voltage of transformer No. 2. Then either from *a* or from *a*₁ to the intersection with *bc* represents the voltage of transformer No. *1*, depending upon whether the polarity is positive or negative.

821—Connecting Auto-Transformers—The high tension winding of a single-phase, 300 k.v.a., step-up transformer consists of three sets of coils, which, when connected in series, gives a pressure of 30 kilovolts when the primary voltage is 2 000. Compelled by special circumstances, I want to use three of these transformers as auto-transformers, (using the high tension windings only) to raise the potential in a certain three-phase transmission line from 10 kilovolts to 20 kilovolts. If I make connections as shown in Fig. 821 (b) and apply 10 kilovolts between leads *A* and *B*, I apparently can get 20 kilovolts pressure between leads *A* and *C*. For single-phase transmission this scheme would be satisfactory, but the actual transmission is to be three-phase. *a*—How shall I connect the bank of three auto-transformers to the 10 kilovolt, three-phase line to raise the potential from 10 to 20 kilovolts? *b*—What percent of the full capacity of the transformers shall I expect to get out of the combination? M.L.S. (MEX.)

The transformers can be operated as auto-transformers to transform from 10 000 to 20 000 volts, three-phase, when connected as shown in Fig. 821 (c), provided each of the three groups of coils is wound for the same voltage. If there is any difference of voltage between the two groups that are connected in parallel, there will be a circulating current that may burn up the windings. The output of the three transformers will probably not be more than about 375 k.v.a., although this will depend upon the overload capacity under normal operating conditions. W.M.M.

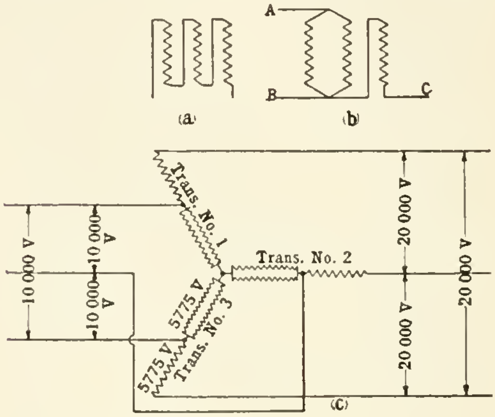


Fig. 821 (a), (b) and (c)

822—Totalizing Three-Phase Power on Wattmeter—Is it practicable from technical and commercial standpoints to record on one wattmeter the power of several three-phase circuits of the same voltage, by use of parallel connection of the secondaries of the current transformers to the current coils of a polyphase wattmeter? The circuits on the high-tension side of the 100 000/12 000 volt power transformers are connected permanently in parallel. The feeder bus-bars may be parallel through bus-bar switches but do not necessarily operate so. J.M.

It is common practice to connect the secondaries of two or three current transformers in multiple as shown in Fig. 822 (a) for totalizing the load in several circuits which have equal and synchronous voltages. This method of totaling power is discussed in "Meter and Relay Connections," by Mr. H. W. Brown, in the JOURNAL for May, 1909, in which the present diagram appears. When a considerable number of transformers are so connected there probably would be an appreciable error in case only one or two of the circuits are alive. The impedance of transformer winding is very high as compared with that of the wattmeter series coil and consequently very little current is shunted away from the meter unless the number of inactive transformers is large in comparison with the number of live wires. Of course, the wattmeter must have a series coil with a current carrying capacity equal to the sum of the secondary currents of the transformers. This point is sometimes overlooked in specifying apparatus for such measurements. H.B.T.

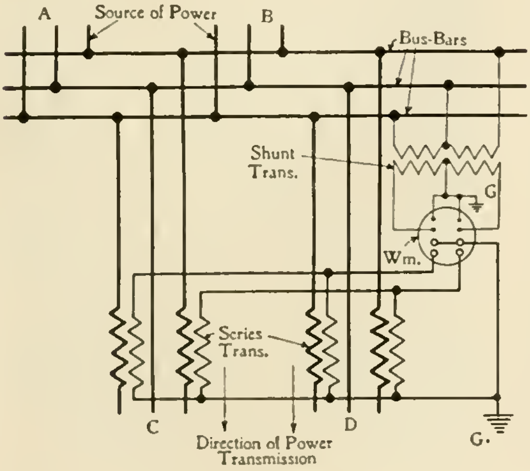


Fig. 822 (a)

823—Effect of Cutting Out Coils In Induction Motor—What would be the effect of cutting out one set of coils on a six-pole, 1 200 r.p.m., 72 slot, one-half hp, 220 volt, 60 cycle induction motor, there being four coils to the set? C.J.B. (ILL.)

a—If the winding is connected in series-star, the current in the three phases will become unbalanced; the power-factor and efficiency will be reduced, and the heating will be increased. The motor will also be less quiet in operation than originally. If the normal temperature rating is sufficiently liberal, the motor will probably operate without injurious heating. *b*—If the winding is connected in parallel-star, series-delta, or parallel-delta, the current in the three phases will become unbalanced as in case *a*, but to a greater extent, due to circulating currents in the primary winding. It is doubtful if such a motor would run any length of time without excessive heating. G.H.G.

824—Special Two-Phase — Three-Phase Connection—In one of the electrical engineering handbooks I find the transformer arrangement indicated in Fig. 824 (a) for changing from two-phase to three-phase. Please give vector diagram showing phase relations of the various component voltages and explain the connection. J.E.K. (PENNA.)

Three-phase voltages cannot be obtained from a two-phase circuit by the use of two transformers as shown in Fig. 824 (a). The fundamental trouble lies in the fact that the required phase shifting cannot be obtained by *impressing* two voltages, differing in phase from each other, on two different parts of the primary winding of each of the two transformers. If the connections are reversed as shown in Fig. 824 (b), three-phase voltages can be obtained as shown in the vector diagram, Fig. 824 (c), which assumes that 100 volts, three-phase is desired. For various information on two-phase—three-phase method of transformation see articles and question box references on this subject on page 17 of the Nine Year Topical Index, under "Transformers." W.M.M.

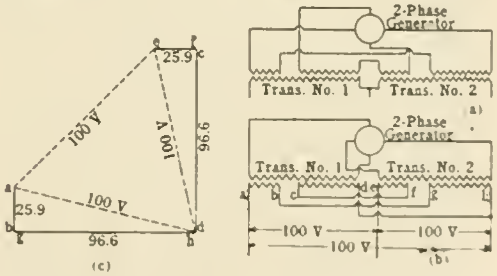


Fig. 824 (a), (b) and (c)

825—Insulation Resistance of Alternators—Before starting a 10-000 volt alternating-current generator what resistance should the insulation show between armature and ground? Could a Megger reading from 5 000 ohms to 40 Megohms be used satisfactorily to measure it?

J.C.H. (ONTARIO.)

Common practice is to dry out the machines by running on short-circuit with a weakened field until the insulation resistance reaches a minimum value and begins to rise. When it reaches the maximum value, or approximately one megohm per 10 000 volts breakdown test, it would be safe to make the high voltage breakdown test. A megger, reading from 5 000 ohms to 40 megohms, could be used for this purpose. I.L.G.

826—Potential Transformers and Meter Connections—We are installing new polyphase meters which call for two current transformers and two potential transformers. Instead of buying two potential transformers, one has been secured and I am supposed to use the other potential transformers already in use for synchronizing rotary converters and furnishing current for the signal lamps. The new meters call for a ground for the potential transformer on the outside lines of the secondary, while our present system is grounded on the second line. Can I change the connections so that both transformers will be grounded on the middle line? Will it affect my meter? I cannot now change my transformers on the system, because it would throw me off on synchronizing signal lights. Fig. 826 (a) indicates the correction called for by the diagram and Fig. 826 (b) shows the way I want to arrange the meter if possible. C.W.R. (PENNA.)

In Fig. 826 (a), the current and potential transformers are so connected to the meter that the direction of current, at any given instant, is the same through the meter coils. For example, the bottom row of binding posts are connected to the ground or common return wire. Let us assume that for a given instant the current is flowing through the ground wire back through the meter to the instrument transformers. This means that the current direction in the meter is from the lower binding posts to the upper binding posts. In the scheme of connections of Fig. 826 (b) as desired in the question, it is to be noted that with the same assumption as before (viz., that the current is to flow from the common wire through the meter back to the transformers) it will be found that the current direction of the potential transformers is reversed from that of the current transformers, or in other words, the potential circuit is 180 degrees out of phase with the current circiut. Figs. 826 (c) and (d) show the proper connections to the meters employing the connections desired for the potential transformers, i.e., with the middle or common wire grounded. In Fig. 826 (c), the same primary and secondary connections of the instrument transformers have been retained; simply the connections at the meter have been reversed. In Fig. 826 (d), the connections of the current transformers have been reversed, which allows the common grounding of the lower meter binding posts, the same as employed in the diagram sent with the meter. This last scheme of connections is probably the best one to employ. The small arrows show the directions of current in the respective wires. The principle to be remembered in making polyphase wattmeter connections is, that the current in the series and potential coils of the meter should be in the same direction in order to obtain proper reading of the meter. This will, no doubt, be found to be emphasized in the book of instructions received with the meter. There is a possibility of the meter readings being slightly inaccurate, due to the extra

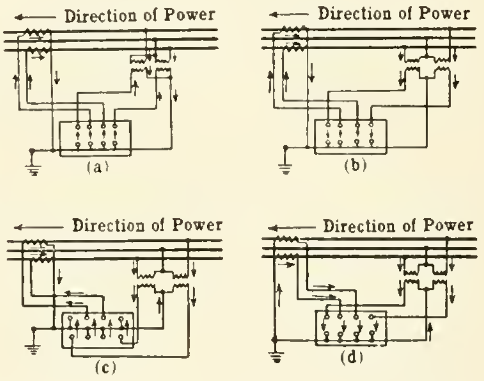


Fig. 826 (a), (b), (c), and (d)

load on the one potential transformer, providing this lamp load is heavy enough to cause an appreciable drop in the circuit of that particular transformer. H.A.T.

827—Synchronous Motor Application in Pulp Mill—In a certain mill a 750 ampere, three-phase, 60 cycle, 440 volt alternator has been installed to furnish current for several induction motors. *a*—It is proposed to install a 400 hp synchronous motor to run a pulp grinder, and connect the motor direct to the grinder shaft, in which case it should run at 240 r.p.m. Would it be advisable to use a belted induction motor for bringing the synchronous motor up to speed? *b*—As the grinder would not have any load in starting, excepting the friction of its bearings, it would probably not require over 25 hp to start the grinder; what additional power would be required to bring the motor up to speed? *c*—On the starting panel it is proposed to mount an indicating kilowatt meter showing the total power taken by the other motors in the mill, so that the operator can regulate the load on the grinder, which is driven by the synchronous motor according to the power available from the generator. All of the induction motors would not be running at the same time. The other apparatus on the starting panel would be a synchroscope, direct-current voltmeter and ammeter for the exciter, and an oil switch in the main circuit of the motor. Is this correct? How would you determine when the motor field has the correct excitation? *d*—Could a self-starting synchronous motor be used in this case, and which type of machine would be most expensive? J.S.S. (MICH.)

The three-phase k.v.a. capacity of the alternator would be approximately 570 k.v.a. The individual sizes and total power requirements of the induction motors are not stated, but it is assumed from the question that with the individual induction motor loads changing from time to time, the alternator is not loaded at any one time to its full capacity. A synchronous motor could then be added as suggested in the question and could doubtless be utilized to improve the operating conditions, especially as regards the power-factor of the load. Details covering this phase of the matter are given in an article by Mr. Nicholas Stahl in the JOURNAL for October, 1911, page 943. It may be stated briefly that with the synchronous motor field adjusted to the proper strength, the synchronous motor may be made to carry both mechanical load and "condenser load" (*i.e.*, wattless k.v.a.), the latter serving to increase the power-factor of the load on the generator and minimize the actual current drawn from it. Thus, the generator will serve to handle only useful (real kw) load instead of its k.v.a. capacity having to be taken up in carrying out-of-phase current due to the inductive nature of the load. The wattmeter which it is proposed to install on the starting panel will not serve by itself to indicate the power-factor of the load. For this purpose it would be necessary also to have a voltmeter and ammeter. Or, what would be simpler for the present case, a power-factor meter would give the power-factor conditions between the induction motors and the generator. If the induction motor load is relatively large, the amount of mechanical load which can be carried by the synchronous motor will depend on the amount of corrective effect which is required, through increase of synchronous motor field excitation, to raise the power-factor at the generator. (See Figs. 9 and 10, pp. 953 and 955, Oct., 1911.) The generator should not be required to carry much over its normal 750 amperes per phase regardless of the power-factor. The guide in adjusting the field strength of the synchronous motor will be to give not much over normal current per phase in the motor armature if overheating is to be avoided (*i.e.*, 425 amperes per phase). It will probably be well to have an ammeter in the main circuit of the synchronous motor and also one in its field circuit. Unless a synchronous machine is designed for power-factor correction, its fields are liable not to be able to handle continuously the currents required to give large leading or corrective current in its armature and consequently there is a limit to its available capacity for purely corrective effect. If it is designed for such purposes it will handle its full k.v.a. at zero power-factor without undue heating of the fields. Self-starting synchronous motors are obtainable at a small additional cost and would make it possible to start with loads of about 30 percent of normal. It will be evident from the above that upon employing a synchronous motor for power-factor correction on a considerable scale the question as to its design for such purposes should be taken up with the manufacturers.

828—Railway Motor Ventilation— Much has been said along the line of ventilative motors, and as the tendency of the manufacturers is to improve the recent design of motors to produce greater ventilation, is it not possible to overhaul some of the older types of machines so as to increase the ventilation? As it becomes necessary from time to time to completely dismantle an armature, could not additional ducts be punched in the armature laminations or discs, the number, of course, depending on the size of the admature discs; these holes to be in perfect line one with the other, running longitudinally, so as to permit a greater air circulation? It might be said that this would possibly cause the armature to heat on account of the iron losses, due to stamping so much of the metal away in the core, but would not the increased efficiency which would be caused by the increased ventilation overcome the decrease in efficiency which might be caused from stamping out metal in the core? Realizing the fact that most all electric railroads have more or less of old type machines which cannot be disposed of and that might be improved by some ventilator scheme, I thought this matter might prove of general interest. R.N.H. (IND.)

The advantage gained by the present new method of ventilation is due to the commutator bush having longitudinal ducts and a fan being provided to force air through these ducts. Except in these new motors, most commutators have a solid bush which could not be drilled, and without these ducts the advantage of this method of ventilation is lost. Many types of motors will be found to have longitudinal ducts already, which are of sufficient capacity to supply all the air the ventilating ducts can use, so that putting in more longitudinal ducts would simply increase the iron loss without producing any better ventilation. L.T.

829—High Voltage Auto-Transformer Connection — *a* —We have two 25 k.v.a. cycle, 30 000—10 000 to 440 volt, single-phase transformers which we desire to use as auto-transformers by connecting the primaries of the two units in V to a three-phase, 30 000 volt circuit, disregarding the secondary windings of the transformers, and employing the 10 000 volt taps on the primary winding of the two transformers adjacent to their point of connection to obtain a secondary three-phase, 10 000 volt V-connection as shown in Fig. 829 (a). Is this proposed connection possible, practical and safe? *b*—Assuming a transformer such as described used as an ordinary single-phase unit, if a coil on the high-tension side is not needed should such an idle coil be short-circuited?

F.P.M. (CAL.)

So far as phase relation and voltage obtained are concerned, this arrangement would be entirely satisfactory. Its limitations as regards current capacity will be appreciated when it is considered that the primary winding of a 25 k.v.a., 30 000 volt transformer is designed for a normal full-load current of less than one ampere. Assuming that the winding could carry 75 percent overload current continuously without undue local overheating, the total allowable current in that section which serves as both primary and secondary will be only approximately 1.5 amperes. The maximum overload secondary k.v.a. capacity of each unit would be only approximately 10 000 × 1.5, or 15 k.v.a. as the maximum limit. The total power in the primary section (volts × current) must equal the total power in the secondary section (as explained in No. 668, Dec., 1911, and 303, Sept., 1909). Hence the units would be limited to a maximum load of 15 k.v.a. each. *b*—In any transformer, when connection is made to a tap on either the primary or secondary winding so that there will be an idle section or coil, the free end of this section should be left open-circuited.

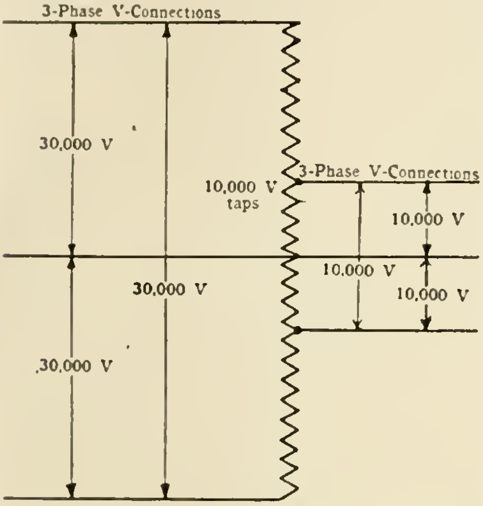


Fig. 829 (a)

Normal voltage per turn is induced in this section, although it is not in circuit, and hence the effect of short-circuiting it would probably be disastrous, as an excessive local current would result. E.R.S.

830—Back Ampere-Turns—What is understood by back ampere turns? C.J.B. (ILL.)

When a direct-current machine is operated with the brushes shifted from the geometrical neutral (forward shift for a generator, and backward shift for a motor), that portion of the armature ampere-turns included between the double angle of brush lead or lag from the neutral produces a flux opposite in direction to the main field flux. These armature ampere-turns, because of their demagnetizing effect, are called "back ampere-turns." For a detailed explanation see Prof. William Cramp's "Continuous Current Machine Design," p. 52, or other good text-book. B.H.C.

831—Voltage Regulation—It is proposed to place a 250 kw, three phase, 50 cycle, 6600 to 250 volt, transformer at the end of a five-mile cable to supply a lighting load. What is the best means of securing automatic regulation on the low tension side within four percent variation? Will the method proposed permit the addition of a second transformer in parallel with the first, working on one set of low tension bus-bars? Or should additional transformers be worked as separate units? Would the proposed method be satisfactory if a motor load having 80 percent power-factor were developed in addition to the lighting load? Are there any details requiring special attention to secure satisfactory operation?

A.H.G. (ENGLAND.)

It would probably be best to use an induction regulator wound for 250 volts and control it by relays (See article on "Feeder Voltage Regulation" in the Journal for Nov., '12, p.985). No trouble will be experienced with the motor load with 80 percent power-factor unless a large motor is switched on, when a sudden change in voltage will take place and some little time will be required to correct the voltage. A regulator operates very quickly, however, and very satisfactory results are obtained in circuits with motor loads. If two sets of transformers and regulators are to operate together it would be preferable to connect the operating shafts of the regulators together rigidly and operate them as one unit. Polyphase regulators operate by shifting the phase of the series coils and if operated in parallel and not kept in phase, a circulating current may result. There would be considerable advantage in operating two sets of bus-bars as the longer circuits could be connected to one and the shorter circuits to the other and a better average voltage could then be obtained. F.F.I.

832—Discrepancy in Meter Calibrations—I have a recording watthour meter, the current coils of which are connected to the secondary leads of a current transformer. There are also connected in series with the current coils an overload relay, an ammeter, an indicating wattmeter, and a power-factor motor. I have the same condition on another motor except that the current coils are connected in series in this instance with another recording watthour meter, a graphic recording wattmeter, an indicating wattmeter, an ammeter, and a power-factor meter. These two meters check against two other wattmeters, being installed under similar conditions except that their current coils are connected in series with an indicating wattmeter only. I find a discrepancy of from one and a half to two percent in the registration of the two sets of meters, the first two running slow. The transformers and meters are the same in construction and make, and should have the same characteristics. The four wattmeters have been checked independently of the transformers and found to be accurate. The four wattmeters are all installed in the same station, therefore, line loss does not enter into the consideration. The effect is more pronounced on heavy load. the power-factor of the circuit being practically constant at all loads, viz., between 90 loading and 90 lagging. R.F.W. (CALIF.)

There is too much load on the current transformers. The question of loading of motor transformers is discussed in articles by Mr. H. W. Brown on "Meter and Relay Connections," which appeared in various issues of the JOURNAL from May, 1909, inclusive. See also "Current Transformer Characteristics," July, 1911, p. 642, and "Grouping of Current Transformers," Nov. and Dec., 1911, pp. 1023 and 1109. W.B.

833—Starting and Excitation of Synchronous Motor—*a*—In starting self-starting synchronous motors, should the motor field winding be short-circuited through the field discharge resistance or left open until ready to close field switch? *b*—What effect is produced on the exciter of such a synchronous motor if the motor falls out of step or if field switch is closed before machine reaches synchronous speed? Does not this tend to neutralize the field magnetism of the exciter; also to damage insulation? *c*—An exciter of this kind refused to generate full voltage. Tests showed four of the six field poles to be devoid of magnetism. Also showed some four field coils to be perfectly cool while remaining two were excessively warm. What was probable cause of this? C.L.G. (TEXAS.)

a—All synchronous motors should be started with the field short-circuited. This can be done usually most conveniently through the field rheostat or exciter armature. The field discharges resistance may be used in case it is designed so as to carry the current without overheating. In case the machine is started with field open its coils are liable to damage from the high voltage induced in the field. There is also an element of danger due to having this voltage on the switchboard.

b—When the motor falls out of step or the field switch is closed with the machine not in exactly step, an e.m.f. is generated in the field coils, which circulates an alternating current through the field coils of the motor and the armature of the exciter. This will in no way injure either machine. The alternating current will tend to alternately increase and decrease the field magnetization.

c—The coils which were cool were likely short-circuited at the terminals, so that current was shunted around the poles. The hot coils were overexcited in any effort to produce full voltage. The short-circuit was probably temporary and was removed in changing the frame and pole pieces. R.A.M.

834—Effect of Synchronous Motor on Line Power-Factor—When using a synchronous motor as a rotary condenser, if it is placed in the station will it raise the power-factor on the transmission line or only through the generator? L.A.F. (MASS.)

The power-factor of the *load* on the station is determined by the relative amount of inductive component of the load plus the inductive effect of the line. An inductive load, such as induction motors, requires a greater amount of magnetic field excitation than a non-inductive load of the same kw (real or in phase) power. If this excitation is furnished at the load by means of a synchronous motor operating with strong field, this serves to relieve the transmission line and the generator at the power house of the additional current required to supply this excitation to the load. As this extra current exists only as an out-of-phase component, its elimination results in higher power-factor of both the line and the generator at the power house. If the synchronous motor is located at the power house, obviously only the power-factor of the load at the generators is raised while the line will have to carry the wattless (or out-of-phase) exciting current to the inductive load. This is discussed in an article by Mr. N. Stahl in the JOURNAL for Oct, 1911, Fig. 826, and in article on "Improving Power-Factor of Industrial Load" in the JOURNAL for July, 1912. E.R.S.

835—Parallel Operation of Direct-Current and Double-Current Generators—In a street railway plant a direct-current generator driven by water wheel and a double current generator driven by steam engine are operated in parallel on direct-current bus-bars with an equalizer connecting the two machines between the negative brushes and the series field, the latter being connected to the negative bus-bars. The double current generator is three-phase on the alternating side. Suppose there is at times sufficient alternating-current load to appreciably slow down the double-current generator *B*. Will not the direct-current generator *A* send current through *B* and tend to drive it as an inverted rotary converter thereby making it possible to utilize both *A* and *B* to supply the alternating-current load? With connections as in Fig. 835 (a) the current from *A* will apparently follow the arrows and practically cut out the series field. Aside from the question of limit of capacity of *B* I should like to know if the above operation is not practicable.

L.A.F. (MASS.)

As the alternating-current load comes on, the reduced speed, together with the internal inductive drop of *B*, decreases its terminal voltage, thereby shifting part of all of its original direct-current load to *A*. If the entire direct-current load were shifted to *A*, no direct-current would flow in the armature of *B*, although its series field would still retain the same excitation as formerly, its current passing through the equalizer and returning to the armature of *A*, as indicated in Fig. 835 (a). If the voltage of *B* drops off still further, *B* tends to operate as a motor from *A*, current flowing through the local circuit consisting of the two armatures and positive and equalizer bus-bars. This would not alter *B*'s series excitation, however, as this is entirely dependent upon the direct-current load and the relative resistance of the two series fields between the negative and equalizer buses. It is evident, therefore, that either poor engine regulation on the double-current generator or a heavy internal inductive drop from the alternating-current load would cause *B* to operate inverted, and to this extent *A* would assist in supply alternating-current load. See Nos. 57, May, 1908, 643, November, 1911, and 718, March, 1912. R.H.T.

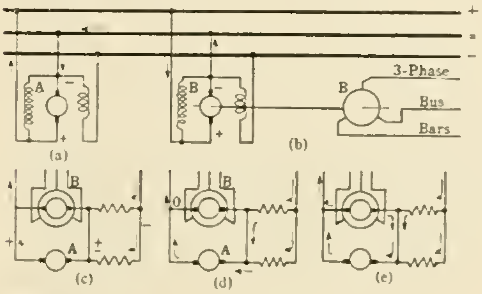


Fig. 835 (a), (b), (c), (d) and (e)

836—Performance of Induction Motor at Different Speeds—Suppose a standard induction motor with squirrel cage secondary runs at 900 r.p.m. synchronous speed on a 60 cycle circuit, and it is desired to rewind this motor for a different speed. How much variation in speed either way from original can a motor stand? Or putting the question in another way, suppose it is desired to rewind the motor to run either at 720 or 1 200 r.p.m. synchronous speed; how will the operating characteristics, such as slip, torque, hp and heating be affected? Can the secondary stand much increase in speed?

F.F. (YUKON TER.)

The variation in speed that an induction motor can stand depends on how much the iron core is saturated, and also on the heating of the motor. If saturation is not too high, the number of poles can be decreased and if the heating is not too great, the number of poles can be increased. In changing from eight poles to ten or six poles, the output varies approximately in proportion to the speed. The power-factor at higher speed will be better as the magnetizing current and the leakage are lower. On the contrary the power-factor will be worse at lower speeds. At the higher speed, (6 poles), the motor will have higher pull-out torque, better efficiency and slightly less slip and the opposite will happen at the lower speed. The torque will remain practically the same at all speeds if the hp varies with the speed. For ordinary standard motors, the rotor can stand mechanically all variation in speed from 6 poles to 12 poles inclusive. G.P.

837—Slip Regulators—In a large electrical factory I saw a piece of apparatus called a slip regulator. Will you please tell me what this is used for and how it operates. R.D.W. (PENNA.)

These regulators are used for load equalizing purposes on wound-rotor induction motor driving machines which are subject to a fluctuating load such as mine hoists, unloading docks, or rolling mills. These prevent sudden overload on the motor, generators and transmission line. The regulators consists of three movable insulated electrodes and three fixed electrodes in an iron tank. Directly over each fixed electrode is a movable one; the latter three are connected to the slip rings of the motor. The movable electrodes are raised and lowered by a torque motor or "motor magnet," thereby increasing or decreasing the resistances. The motor is so connected through series transformers to the line that when the load exceeds a predetermined value the electrodes are raised and the liquid resistance in the rotor circuit is increased, which slows down the motor, causing the flywheel on the motor shaft to take the load. On the other hand, if the load falls below this point, the torque motor allows the electrodes to move together thereby decreasing the resistance, which causes the motor to accelerate the flywheel and thus tends to keep the load up to this predetermined point. H.W.B.

838—Unsymmetrical Form Wound Armature Coils—Why are armature and stator coils made of different lengths on the two sides going in the slots. Should the short side go into the bottom of the slot. It is noted also that the end connections of such coils are also of unequal length on the two halves at each end. W.F.S. (CALIF.)

The two sides of the form wound type of coil and the two halves of the end connections are often made of slightly different length, the purpose being to make it easier to arrange the end portions of the coils without interference. The mechanical arrangement is the prime reason involved. The short side of the coil should always go into the bottom of the slot. G.E.M.

839—Galvanized Iron Wire—What is a good practical way of telling whether iron wire is probably galvanized so that it can be used without danger of rusting. W.I.H. (D. OF C.)

The following is the standard method of testing galvanized iron or steel. A solution is made up consisting of copper sulphate crystals dissolved in cold water, in about the proportions of 36 parts by weight of crystals to 100 parts by weight of water, and a little curpric oxide is added to the solution. After filtering the solution, it should have a specific gravity of 1.186 at 65 degrees F. Samples of the wire should be prepared so that they can be conveniently immersed in the solution. The temperature of the solution should be maintained at 62 to 68 degrees F., and the sample should be immersed for one minute, then washed and wiped dry. Immerse a second, third and fourth time, each time for one minute, and wash and wipe dry. Bright metallic copper will deposit on the sample and, as soon as the zinc is removed, will adhere firmly to the exposed iron. The wire should in all cases withstand the four dips without the copper deposit adhering. B.W.E.M.

1724

PERSONALS

Mr. L. O. Veser, who has been in charge of construction work for the Mahoning & Shenango Railway & Light Company, of Youngstown, Ohio, has been appointed chief engineer of the company, succeeding Mr. G. N. Lemmon, resigned. Mr. W. A. Acker, formerly superintendent of transmission lines of this company, has been appointed electrical engineer. Mr. W. A. Butler, who has had charge of the power house at Youngstown for a number of years, has been appointed engineer of power houses of this company.

Mr. E. R. Spencer, formerly an assistant editor of THE ELECTRIC JOURNAL, is now employed by the Allis-Chalmers Company as commercial engineer, and is for the present located at their Pittsburgh office.

Mr. Frank F. Fowle, one of the editors of the *Electrical World*, has severed his connection with the McGraw Publishing Company to resume consulting engineering practice with offices at 69 Maiden Lane, New York City.

Mr. E. T. Penrose, formerly of the Philadelphia district office of the Westinghouse Electric & Mfg. Company, later general manager of the Penn-Central Light & Power Company, of Altoona, and more recently electrical engineer of the Pennsylvania Coal & Coke Company, has recently joined the staff of the Electric Bond & Share Company.

Mr. Arthur Walser, formerly of the Philadelphia office of the Fort Wayne Electric Works, has changed his position to the power and mining department, General Electric Company, First Nat'l Bank Bldg., Denver, Colorado.

Mr. H. W Smith, who was on the engineering apprenticeship course of the Westinghouse Electric & Mfg. Company, 1909-1911, is returning to Australia to take up engineering work there. After leaving Pittsburgh Mr. Smith was engaged in sales work in the Chicago and Milwaukee district offices, and later was engaged in railway work with the Chicago, Lake Shore & South Bend Railway and in central station work with the San Diego Consolidated Gas & Electric Company, San Diego, Cal.

Mr. W. F. Wells has been appointed general manager of the Edison Electric Illuminating Company of Brooklyn, to succeed Mr. W. W. Freeman, who recently resigned to become vice-president and general manager of the Alabama Interstate Power Company, Birmingham, Ala.

Mr. S. P. Grace, plant superintendent of the Central District & Printing Telegraph Company at Pittsburgh, has removed to Philadelphia, where he has been appointed engineer of outside plant of the Bell Telephone Company of Pennsylvania. He is succeeded at Pittsburgh by Mr. B. Stryker, of the Bell Company at Harrisburg, Pa.

Mr. R. F. Gooding, of the Allegheny County Light Company, has accepted a position in the switchboard engineering department of the Westinghouse Electric & Mfg. Company at East Pittsburgh.

Mr. Henry T. Gayley, formerly of the sales department of the Westinghouse Electric & Mfg. Company, at East Pittsburgh, and more recently of the Philadelphia district office, has accepted a position as engineer with The United Gas Improvement Company, Philadelphia, Pa.

The National Engineer for November, 1912, contains a reprint of the article by Mr. W. A. Dick, entitled "Notes on a Large Unipolar Generator," from the JOURNAL for September.

PITTSBURGH A. I. E. E. ANNUAL BANQUET

The annual banquet of the Pittsburgh Section of the American Institute of Electrical Engineers is to be held February 8th at the Hotel Schenley. The list of speakers includes,—Mr. H E. Longwell, consulting engineer of The Westinghouse Machine Company, toastmaster; Mr. Ralph D. Mershon, president of the Institute; Chancellor McCormick, of the University of Pittsburgh; Dr. Walther Riddle and Mr. Maurice Knowles.

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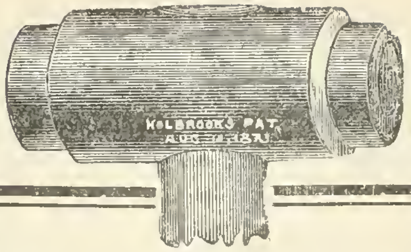

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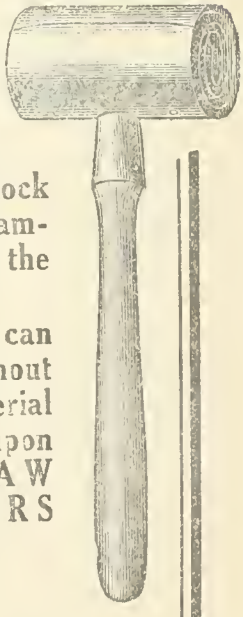

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THE
ELECTRIC JOURNAL

Vol. X MARCH, 1913 No. 3

Progress in Industrial Motor Design

Industrial progress depends upon progress made; first, in simplifying the method of production; second, in increasing the economy in the use of materials constituting the manufactured product, and third, in adapting a product so that it can be widely and usefully applied. In the industrial applications of electricity, progress depends largely upon the adaptability of motors to the requirements of various industries. The most successful motor for all around application is one which has good electrical and mechanical performance, and that is of such proportions that it can easily be applied as a part of the machine it is to drive. The more fool-proof a motor is the wider will be its field of application.

The article by Mr. C. W. Starker, entitled "A Step of Progress in Motor Manufacture," in this issue of the JOURNAL, describes how a direct-current motor, involving an entirely new departure in design, is being constructed and shows the decided simplicity of its operation and the high quality of material used. Before adopting such radical changes in motor design no detail of design, and no method of construction and no material has been adopted until it has been proved beyond the possibility of doubt to be the best available for the purpose. All non-essentials have been omitted, the aim having been to meet the most general demands in the most satisfactory manner. Superfluous material and unnecessary losses have been eliminated at every possible point, resulting in a motor of minimum weight, consistent with the requiste strength and high efficiencies.

At first sight, the light weight of these motors may seem to be obtained by economizing too much in material. This, however, is not the case; the light weight is due entirely to the inherent characteristics of the motor and the quality of the material used in its construction.

One of the principal features in determining the success of a direct-current motor is its commutation. Before commutating poles were used, the limit in overload capacity on this type of motor was its commutation. By proper design of commutating poles, this is no more the case but, like the squirrel cage induction motor, if properly designed, the commutating pole motor is limited in overload capacity by temperature rise only. Among other things, commutation depends on the ratio of the number of armature ampere-turns to the number of field ampere-turns, and on the air-gap. For good commutation a non-interpole motor must have a strong field, i. e., a large amount of copper on the field poles and large cross-section of iron in the magnetic circuit. The counteracting ampere-turns produced by the armature current must be comparatively small; hence, the number of turns on the armature must be kept down. The air-gap must also be large so as to offer sufficient reluctance to the magnetomotive force produced by the armature ampere-turns and to produce a stiff field, i. e., a field not easily distorted by armature reaction.

In an interpole motor, however, the armature ampere-turns, are counteracted by the interpole windings. More armature turns, a smaller air-gap, lighter field coils, and smaller cross-section of the entire magnetic circuit are, therefore, possible. In the new type motors these principles have been utilized to the maximum extent. With a slightly decreased air-gap and the use of interpoles, the weight of the entire magnetic circuit has been reduced, resulting in considerably lighter motors, without sacrificing electrical performance or mechanical strength. The reduction in the cross-section of the magnetic circuit does not affect the rigidity of the motor, since the section necessary for magnetic purposes is far in excess of that required for mechanical strength.

When commutating poles are used it is very important to keep the brushes set on the neural—a definite position. Thus, as in railway practice, it has been found best practice, on industrial commutating-pole motors, to mount the brushes in a fixed position. By doing so, a large number of troubles due to the improper setting of brushes, by those not familiar with the operation of electrical machinery, are eliminated. Thus, a direct-current motor has been developed that is practically as fool-proof as the squirrel cage induction motor and that can be operated without the supervision of skilled electricians.

The success of this type of motor, in the short time it has been on the market, is an indication that this mehod of consruction, which is still in infancy, will find successful application in other classes of apparatus in the electrical industry. The advantage gained thereby will have a marked effect upon the progress made in the application of electricity to the various industries on account of the simplificaion of manufacturing operations, resulting in the possibility of manufacturing in large quantities and thus obtaining quick deliveries.

A. G. Popcke

Growth of Central Station Power Load

During the Summer of 1906 a motor salesman in the employ of one of the large electrical companies opened a campaign in Western Pennsylvania and Ohio to sell motors through the central stations. The plan was to demonstrate to the manufacturers in this district that it would be economical to abandon their steam power plants, use motors to drive their machinery and purchase power from the local electric light company. One of the greatest difficulties encountered was to get the necessary support and coöperation from the lighting companies. It was seldom that they would lend active assistance towards closing business, and the rates quoted would frequently be discouragingly high. Rarely would they name a rate lower than five cents per kilowatt-hour, and many times eight cents would be the best figure quoted. Sometimes it would require as much effort to get the support of the lighting company as was afterwards required to close a contract with a power customer.

Another difficulty was the attitude of the manufacturers towards central station service. When opening a negotiation with them the utmost diplomacy had to be used in presenting the proposition. Often it was first necessary to interest them by explaining the advantages of electric drive, as it was not advisable to take up the question of power until their confidence had been secured. They judged the cost of purchased power by its cost for lighting in their homes. This attitude was, in a measure, due to the attitude of the lighting companies, many of whom were entirely satisfied with their lighting load. Their power field they considered to consist of furnishing service to a few small users for operating motors to drive ice cream freezers, meat choppers, coffee mills, etc.

During the next year several negotiations were closed with manufacturers, who were then considered large users for central station service. Other lighting companies became interested and began to appreciate the important effect that power business had upon their revenue. Rates were reduced, and managers were more ready to coöperate with any of the motor salesmen who would lend them assistance. Practically all the deals closed were with small manufacturers. It was seldom that the total motor capacity exceeded 100 horse-power. Even at this time many believed that it was only the smaller manufacturers who could afford to use central station service, and that the larger ones could make power as cheaply as they could buy it.

The business secured, however, represented the highest type of salesmanship—creating business. In nearly every case the manufacturer had not even thought of making a change. The proposition put before him was so out of the ordinary that it aroused his curiosity. The enthusiasm and confidence of the parties presenting the proposition would finally change his curiosity into real interest. After his interest had been secured careful handling and patience were required to lead him along until his interest became a desire for the service. This class of business required little engineering—it was essentially a sales proposition.

As time went on a few power companies began to appreciate the fact that the larger manufacturers could afford to use their service. The success of these few central stations spurred others to greater activity. Many of them thought that to get this business required only a low rate. This secured a certain amount of business, but simply naming a low rate will not secure all of the business obtainable. Rates are quoted at so much per kilowatt-hour, and it is an exception to find a manufacturer who knows the quantity of power he requires. Therefore, he is unable to appreciate whether he is offered a good proposition or not. This method of selling power has a tendency to bring about lower rates than necessary, due to the fact that the power companies are always in competition with the rate at which the manufacturer believes he is producing his own power. He usually arrives at his estimate by asking his man in the engine room what the average load is. He then multiplies this by the number of hours operation and divides it into his total operating costs. The chances are that he is really generating a considerably smaller amount of power and again, in his costs, he entirely neglects his fixed charges. Of course, with such figuring he finds that he is generating power at a very low cost.

The central stations who are selling their service to the large manufacturers at equitable rates are the ones who do the necessary engineering in the prospect's plant to show the quantity of power required and the present cost per unit. These companies are then in competition with the manufacturers' actual cost—not estimated costs. Also, with his information at hand the manufacurer can then make a comparison with the rate named by the lighting company. He can see the actual saving to be made, along with the other advantages to be secured. This enables the lighting companies to close business at a higher rate than would be possible if this work had not been done. Selling power to the large manufacturers requires a combination of both engineering and sales experience—engineering to obtain the necessary data, and salesmanship to present it in a convincing manner and close the deal.

An idea of the growth of the central station power business can be had by referring to the U. S. Census. This shows that in 1912 the total income of the central stations from motors was $85 534 000; an increase of 764 percent in ten years. This growth is even more wonderful when it is considered that the major portion of this increase was secured during the past five years. The gross income of all power companies in 1912 was $377 630 000—an increase of 340 percent in ten years. The resident and commercial customers are using more light than ever before; also the streets are better lighted. However, the income from this source increased 226 percent, as compared with the increase in income from motors of 764 percent. The latter figure indicates the future field of the power companies. A better idea of the important position, now occupied by the central station as an industry, may be formed by comparing its capital of $2 500 000 000, and that invested in all manufacturing cotablishments of $18 428 270 000. In other words, there is 13.5 percent as much capital invested in the central station industry as there is invested in all manufacturing establishments in the United States. The capital of the central stations increased 379 percent in ten years. The primary horse-power increased 417 percent. This indicates that the greater part of the increased capital must have spent for new equipment.

An analysis of the class of power users served by the power companies will show, in almost every instance, that of the total *number* of power users, the majority use purchased power, but offsetting this, it will also show that of the total *horse-power* used in the territory, only a small portion is central power service. This indicates that the power companies have been most successful with the smaller users.

Today the power companies are meeting with splendid success with the larger manufacturers. In the Pittsburgh district there are many installations ranging from 1 500 to 3 000 horsepower, some even larger, now operated by central station power.

Estimates based upon the U. S. Census reports show that today, of the total power used in manufacturing, 12 percent is central station service. At the close of the next ten years we should see at least 40 percent of all power used in manufacturing, connected to the power companies lines. If this is accomplished their revenue from motors will then be $285 115 000, without taking into consideration the probable increase in the demand for power for manufacturing operations during the next decade. This means an increase of 234 percent. Does this figure appear to be over-estimated when we consider that there was an increase of 764 percent during the last ten years? In this period the primary horse-power in manufacturing establishments increased 85.7 percent. At the end of the next period many manufacturers will have outgrown their present power plants and other plants, now giving good service, will have become obsolete or worn out. These will some day be users of central station power.

A. E. RICKARDS

A STEP OF PROGRESS IN MOTOR MANUFACTURE

C. W. STARKER

PROGRESS in the use of materials has usually been marked by an advance from the inferior material easy to obtain and easy to work, to a higher grade of material, requiring a greater degree of development for its utilization. The same process of advancement continuously repeats itself. Buildings and bridges, formerly of wood, progressed to stone and from stone to structural steel. Many household articles are now drop forged or pressed from steel after having gone through the successive steps of development from wood to cast iron, from cast iron to malleable iron and finally to the steel forging. Things which at first glance do not appear to lend themselves very readily to pressed steel construction, like a freight car or a bath tub are now manufactured under the press.

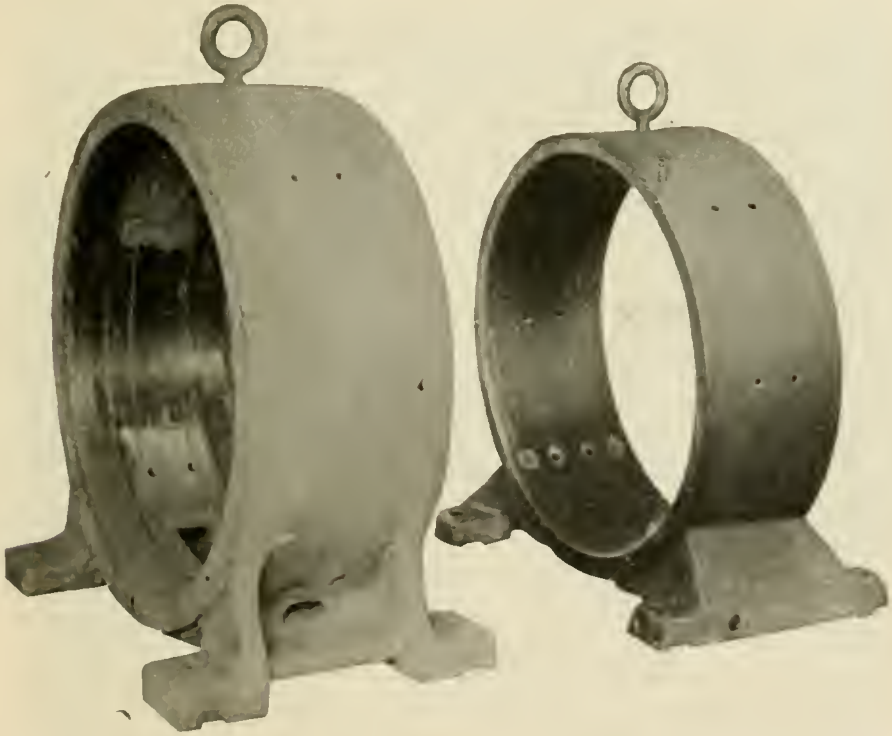

FIG. 1—COMPARATIVE SIZE OF CAST IRON AND ROLLED STEEL FRAMES OF SAME CAPACITY

In all of these cases the new method resulted in more durable work, more accurate duplicates and if only made in sufficient quantities, in a cheaper though better product. In almost every case, parts made by the more advanced process, are lighter and less bulky for the same strength. True, the more perfect the product the higher will be the demand for quality in machine tools, materials and the human element behind it all. While wood work required only simple tools, castings required furnaces and moulding machines; steel plate and wire require rolling mills for their production and steam hammers, forging presses and dies to transform them to the desired shapes.

In the electrical industry one of the newer developments is the "all steel motor" for industrial work. In this article a description is given of the principal processes in the manufacture of the direct current motor known as the "SK" type, as built by the Westinghouse Electric and Mfg. Company, so far as they show the "pressed steel idea" as applied to motor manufacture. The processes described are, of course, not limited to direct current motors; in fact it is contemplated to use the same ideas and principles in the manufacture of other apparatus.

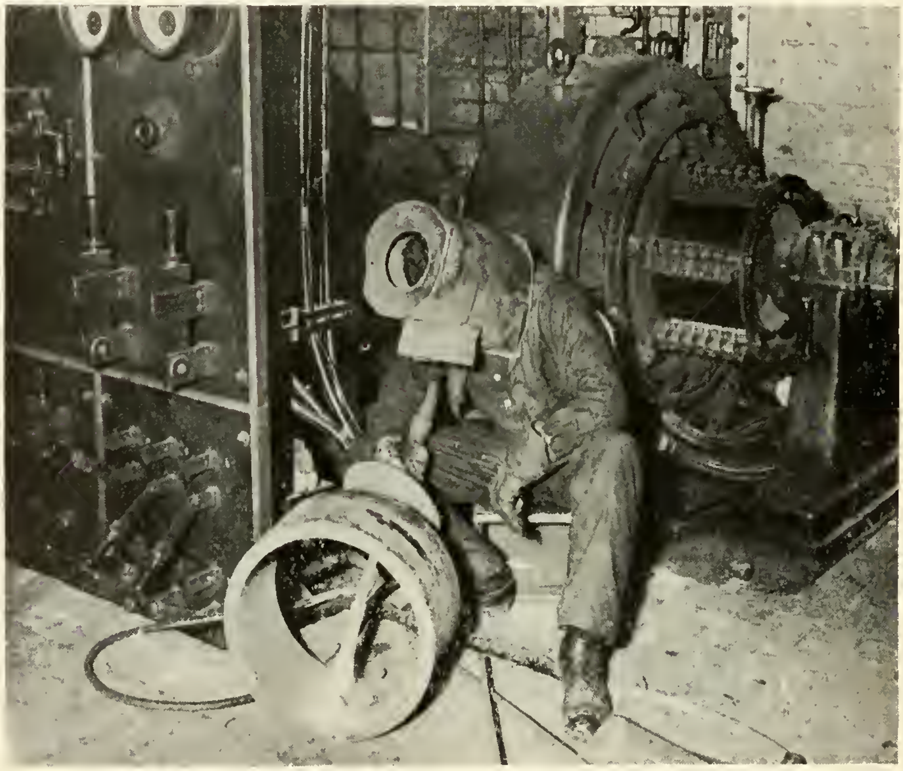

FIG. 2—WELDING FRAME RINGS INTO A COMPLETE MAGNETIC CIRCUIT BY THE BERNARDOS ARC WELDING PROCESS

For direct-current motors, it has long been recognized that cast iron makes a very heavy and bulky yoke, as a very large cross-section is required for magnetic purposes. Cast steel is better, but a good grade is expensive and there is, as with every steel casting the danger of blow holes and often the difficulty in obtaining quick deliveries from the steel foundries. The "SK" motor has a yoke made from hot rolled steel plate which has the same high magnetic characteristics as the punchings used in the armature and can have no imperfections in its structure. The cross-section may, therefore, be small and the yoke will be much lighter. The relative size of the cast iron frame compared with the new rolled steel frame, is shown in Fig. 1, which shows two motor frames of the same capacity.

These frame rings are rolled from straight slabs on a rolling machine especially designed for the purpose. The manufacturing process is substantially as follows: The slabs from which the rings are to be rolled are first sheared to correct length so as to make a perfect joint when formed to a circle. Next they are heated in a furnace located near the rolling machine. The heated slabs are then formed to the desired diameter in the rolling machine. This whole process takes very little time with a well trained crew, although the rings are rolled very accurately to gauge. Rings can be rolled to any desired diameter within the capacity of the machine by the use of different mandrels. At the present time this process is used for motors up to 200 horse-power, requiring rings up to three feet inside diameter, with a maximum thickness of about two inches and a maximum width of about 17 inches.

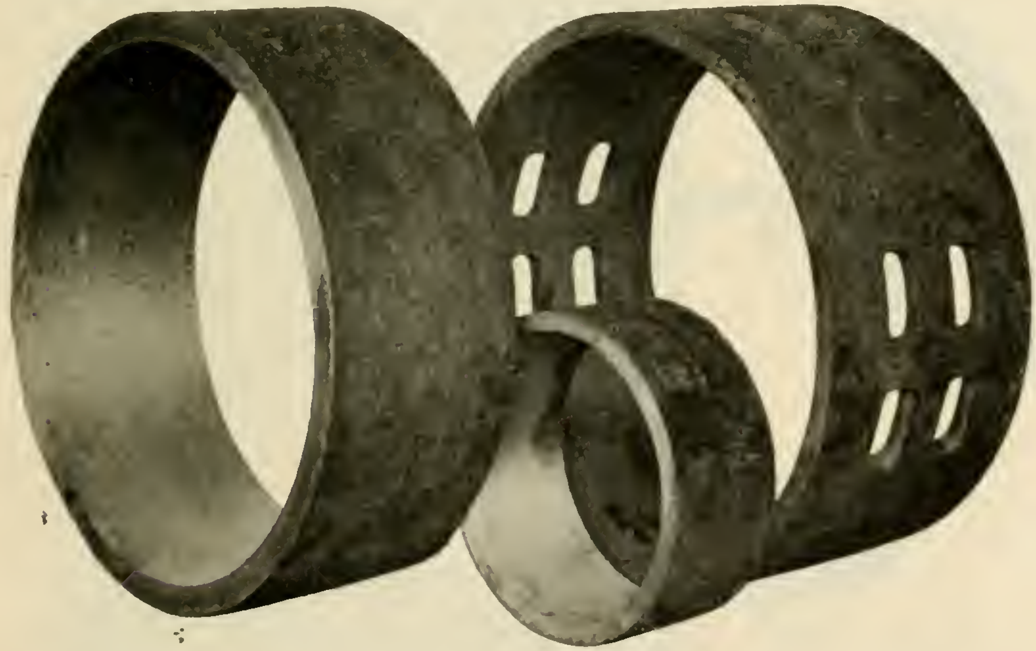

FIG. 3—COMPLETE FRAME RINGS
Ventilated and Non-ventilated Types.

After rolling, the frame rings are welded at the joint, wherever this is required for magnetic reasons. The welding is done by the electric arc welding process,* (Bernardos method). A glimpse of the welding plant installed for welding these frames is shown in Fig. 2. The view shows the converter set in the rear and the switchboard. In actual operation the frame rings rest on a steel plate. One terminal is connected to this plate while the other one leads to the carbon electrode of the welding tool manipulated by the operator. The arc is drawn from the carbon to the motor frame, rapidly raising the metal to the melting point. Additional material to fill the joint, if any is needed, is supplied from a soft iron rod held in the arc. The effect of the rays of the electric arc are such that it is necessary to protect not only the eyes but the face and hands of the operator, as shown in the illustration.

Three different sizes of finished frame rings are shown in Fig. 3. For the purpose of ventilation it is sometimes desirable to have holes in the frame. The frame ring shown to the right has 16 such ventilating holes. They are punched cold before bending, for any thickness of steel plate used at the present time.

It should be understood that the rolling process is not intended to change either the thickness or length of the material, but consists practically only in a bending action.

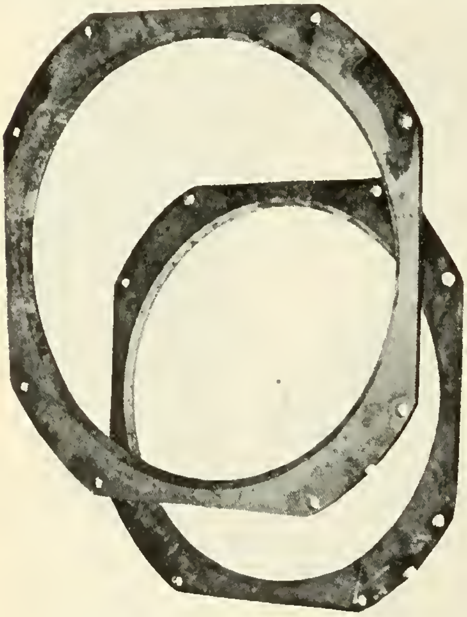

FIG. 4—END PLATES
Obtained by bending a hot rolled steel bar on edge.

Some other products of this rolling machine are shown in Fig. 4; end plates from hot rolled steel for alternating current motors. They are manufactured in large quantities by a process quite similar to that described in connection with the frame rings. Being made of a material superior in structure to any cast material they may be made comparatively thin. This gives them the advantage of taking up less space in the motor, reducing thereby the amount of inactive copper in the windings and reducing the risk from short-circuits between windings and end plates. The steel end plates are also unbreakable. Breakage is a very serious factor in the manufacture of cast iron parts and an item of expense which frequently is underestimated. If a break does occur, it usually happens after the shrinkage strains in the casting are released by removing the hard outer crust of the casting, that is, after the casting is machined completely and a considerable amount of labor has been spent on it.

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*For complete description of the Bernardos arc welding process, see article on electric welding by Mr. C. B. Auel in the Journal for Jan., 1908.

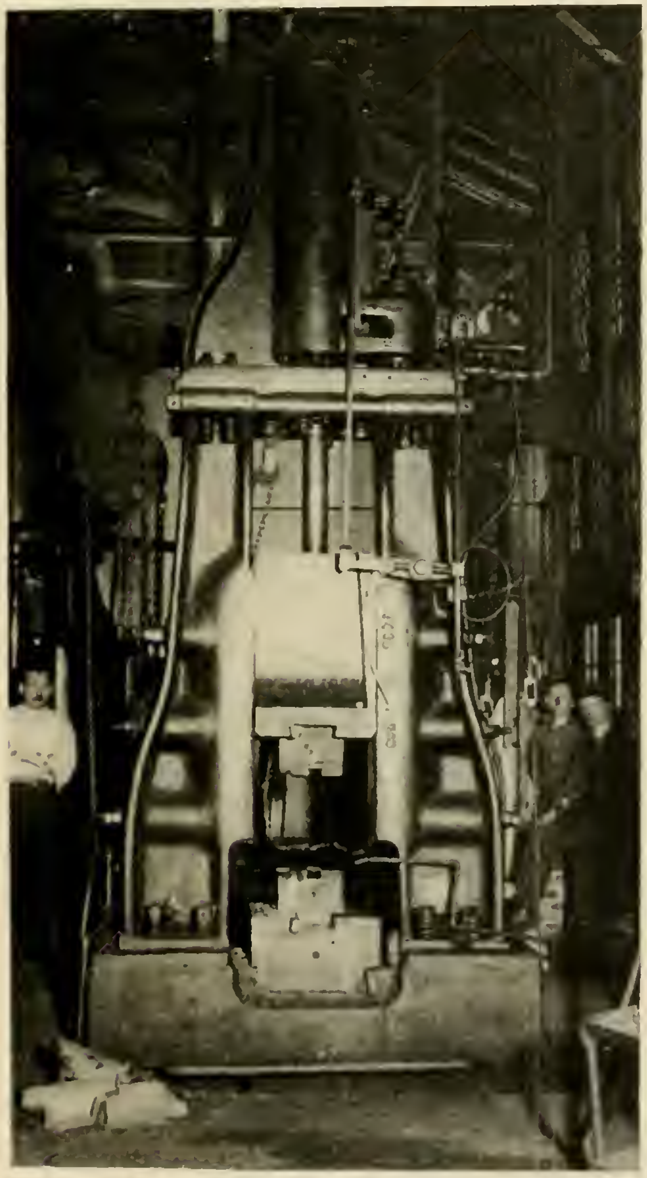

FIG. 5—TWO THOUSAND POUND DROP HAMMER

A 2 000-lb. steam operated drop hammer is shown in Fig. 5. This hammer is used for a great variety of drop forging work. At the time the picture was taken, dies for eye bolts were under the hammer. Other and more novel examples of drop forging work are shown in the following illustrations.

Two different designs of pressed steel feet as used on the smaller motors are shown in Fig. 6. They may be made either in halves or in one piece as shown. A high grade of steel plate is used, 3/16 to ½ inch thick, depending on the size of the motor. This plate comes from the mills in large sheets. The sheets are cut into squares of the proper size, on a 110-inch motor-driven shear, shown in Fig. 7. For each different piece to be pressed or forged the developed shape necessary to produce the desired final result is determined by continued experiments, and blanking dies are then made for punching out the blanks. These blanks are heated and forged to the proper shape, as shown in Fig. 6, by one or two blows of the drop hammer. With a given blanking and forging die every foot will of course be an exact duplicate of the other. All fitting, trimming and removing of unnecessary stock is therefore avoided, a point which greatly aids in quick manufacture.

Another product of this hammer is shown in Fig. 8; pressed steel slide rails used under the motors to adjust the belt tension. To the left a rough forging is shown as it comes from the forging department, then one of the medium sizes and one of the smaller sizes of rails in their finished form, and finally one of the smaller pressed steel bed plates, made in the same way as the rails and similar to the pressed steel foot described above. All of these rails are made from heavy steel plate, amply strong enough to be used for ceiling suspension of the motor and with ample floor area for possible use on a soft foundation. The pressed steel rail or bed plate compared with cast iron has, among others, the advantage of being stronger and unbreakable for a much lower weight. In castings a crack occasionally occurs which is hard to detect, and may pass by the inspector. It is possible that the faulty material may not be discovered even by the most careful inspection until some accident, such as with a motor suspended from the ceiling, has occurred. A forged steel rail is absolutely reliable in this respect.

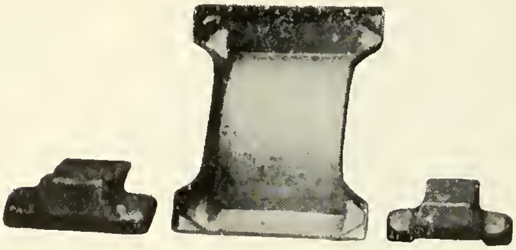

FIG. 6—DROP FORGED FEET, SINGLE AND DOUBLE

Used on smaller motors.

These methods of manufacture involve great expense for tools and dies and still greater expense for the years of experiments and careful study which had to precede their introduction, but it is evident, without enumerating all the different advantages, that the steel forging is not only a greatly superior product, but can also be produced more economically than a casting, provided only that the quantities required annually are large enough to justify the initial investment and that there will be a continuous demand for a large annual production.

The drop forging method described above has in the last few years found a very serious rival in the hydraulic press. The drop

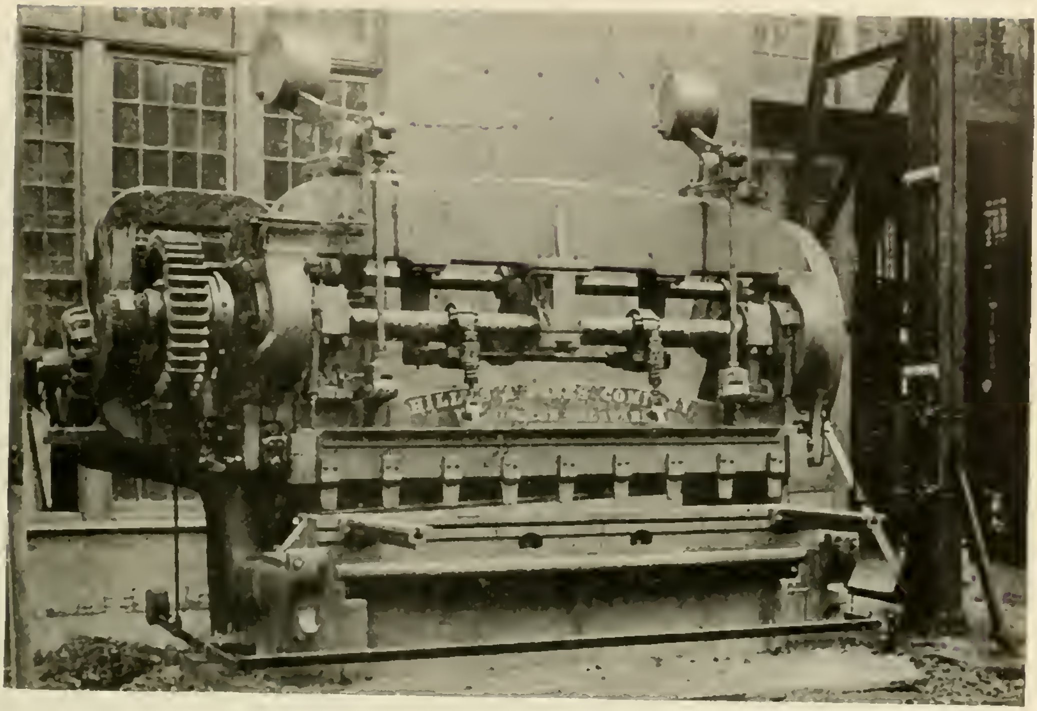

FIG. 7—ONE-HUNDRED-AND-TEN-INCH ELECTRICALLY OPERATED SHEARS
Used in trimming steel plates

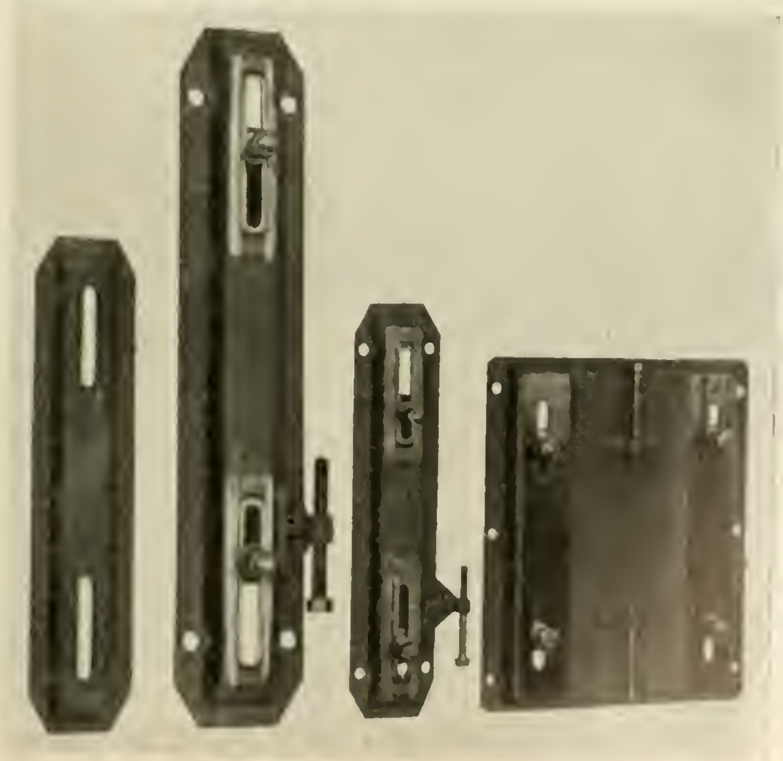

FIG. 8—PRESSED STEEL SLIDE RAILS AND BED PLATE FOR [illegible] MOTORS

hammer, though a very handy and simple tool and suitable for a great variety of forgings, has its limitations, especially as to size of forging and thickness of material. The hydraulic press with its

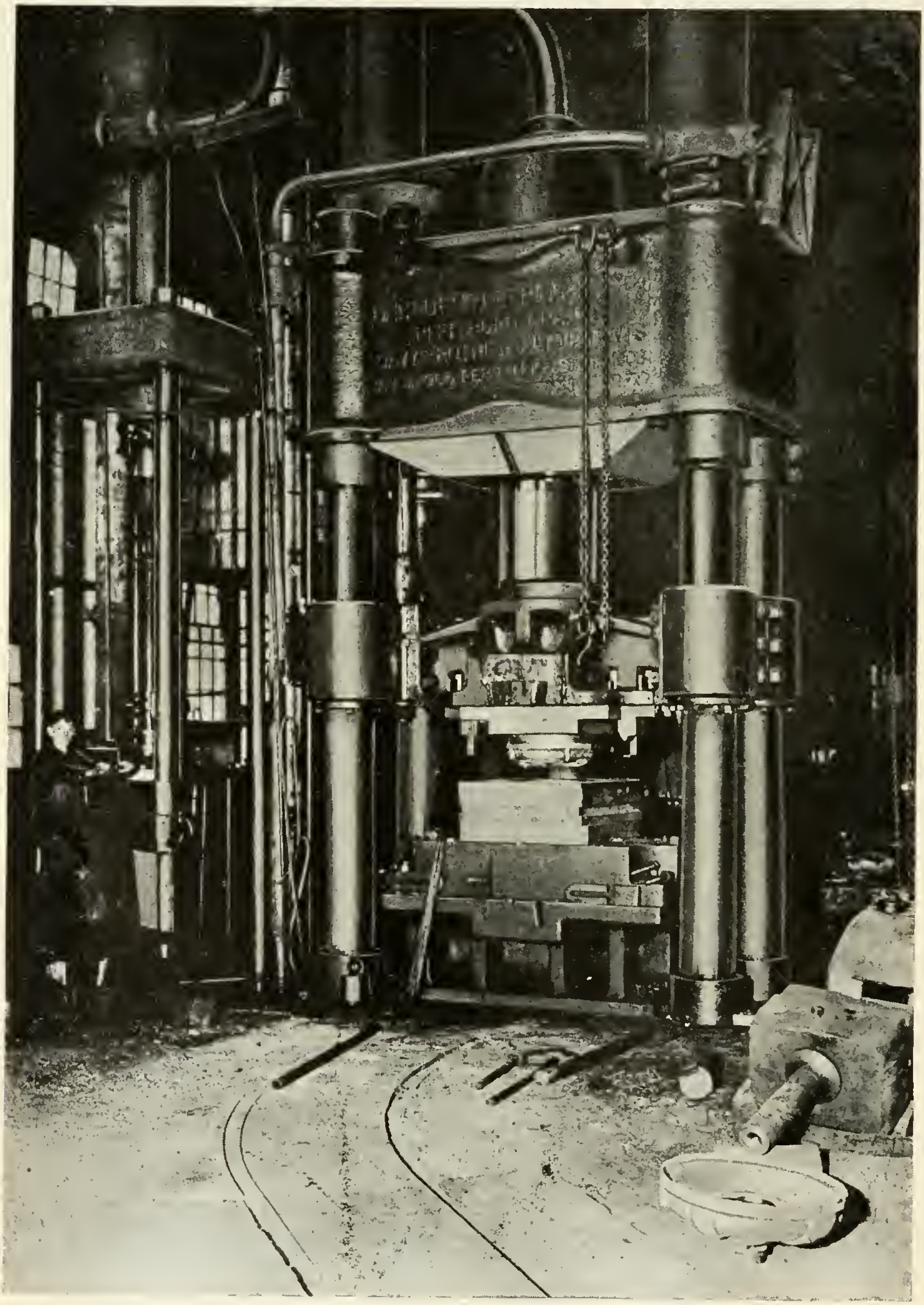

FIG. 9—ONE THOUSAND TON HIGH SPEED STEAM-HYDRAULIC FORGING PRESS OF THE INTENSIFIER TYPE

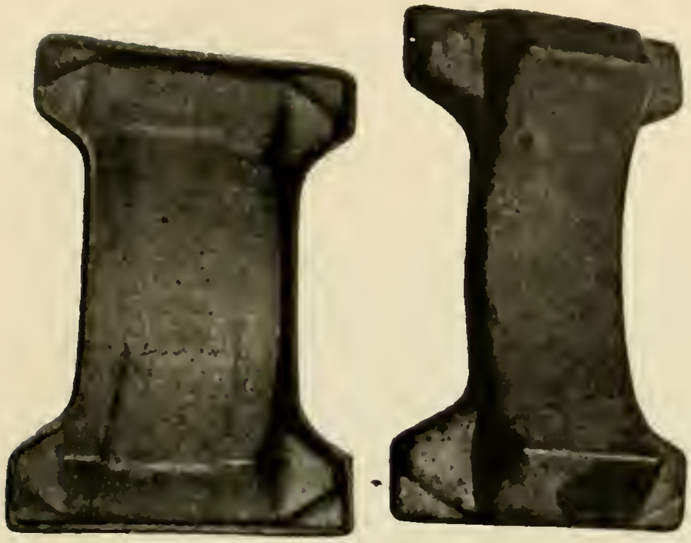

FIG. 10—FEET FOR LARGER SIZED MOTORS
The shape has been worked out to give maximum stiffness for a given weight of material.

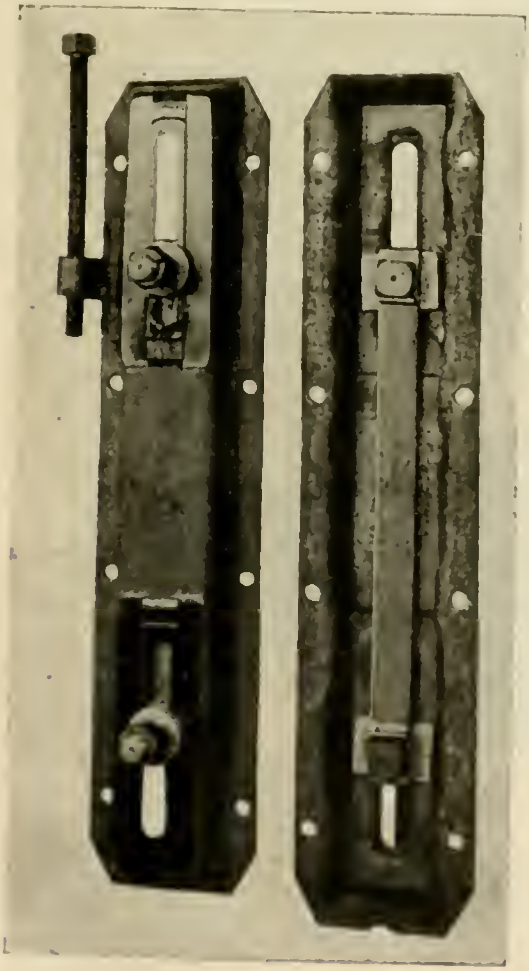

FIG. 11—SLIDE RAILS FOR LARGE MOTOR
Box girder shape gives exceptional stiffness with ample floor area.

slow and steady pressure is preferable to the hammer for many reasons. While hammer blows affect practically only the surface of the forging, the steady hydraulic pressure penetrates to the core even of thick forgings, resulting in a denser and more homogeneous material in the forging. Quicker and better work is possible, for the reason that one application of the press produces the same results regarding reduction of section as five or six blows of the steam hammer, and that with the press the hot steel more readily fills the impressions in the die. Absence of shocks, therefore less risk from breakage of piston rods or dies, the possibility of a lighter foundation and of less expensive dies, easier work for the men and lower power consumption are also points in favor of the press.

A 1 000-ton high-speed steam hydraulic forging press installed for the manufacture of the large pressed steel parts used on industrial motors is shown in Fig 9. This press is of the four-column type and designed according to the Davy principle. The installation consists of the press proper with the main cylinder in the center and the two lifting steam cylinders on top and the steam hydraulic intensifier with the controlling gear and finally the storage tank which appears to the left. This tank is known as the pre-filler, and serves as a receptacle for the water, which is used repeatedly. Sufficient air pressure is supplied at the top of the tank to force the water into the cylinder. A steam pressure of about 150 lbs. per square inch is used in the cylinder of the intensifier. By the action of this steam cylinder a hydraulic pressure of 5 500 lbs. per square inch is produced behind the plunger. The actual forging work is done by the main cylinder, which produces with the hydraulic pressure mentioned a total pressure of 2 000 000 lbs with a possible increase to 2 400 000. The lifting cylinders referred to, serve the purpose of raising the heavy cast steel presshead which holds the upper part of the die. The most interesting part of this press is the control, which is effected by a single lever for all movements, whether actuated by the steam or the hydraulic pressure. The presshead follows the movements of this lever, both as to speed and length of stroke, so that high speed and short strokes may be obtained, or slow speeds as may be required in the particular case. Up to 150 strokes per minute may be made with this press, so that the output in forging or punching is limited only by the rapidity with which the work can be fed into the press. Two different sizes of large pressed steel double feet for motors are shown in Fig. 10. They are hot pressed from steel plate one-half inch thick and in floor dimensions of about two and one-half by four feet. Those familiar with this class of work will appreciate the difficulties that have to be overcome before producing a deep and intricate forging

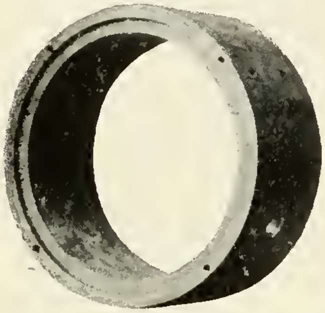

FIG. 12—FRAME RING FOR SMALL MOTOR

Made by the piercing or squirting process from a solid block of steel.

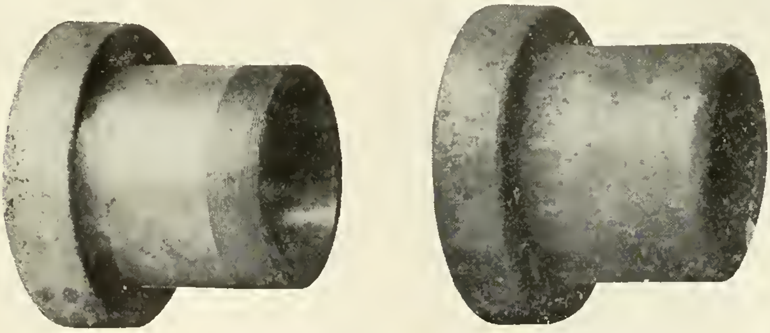

FIG. 13—COMMUTATOR BUSH MADE BY THE SQUIRTING PROCESS

This process insures absolute homogeneity of material.

of this kind. Every foot pressed comes out exactly like the other. The forming is done without any hammer blows or noise, by moving a single lever.

A larger size of pressed steel rail made with this press, seven-sixteenths and one-half inch in thickness and in lengths up to six

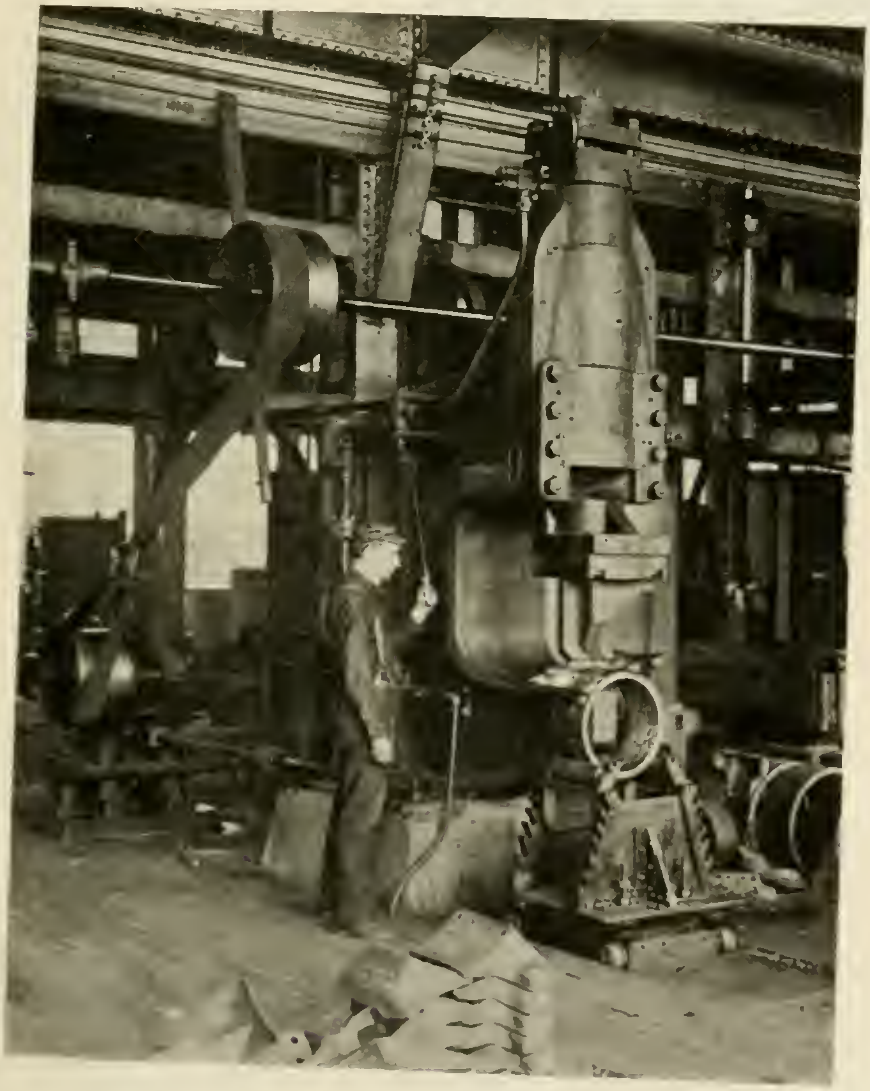

FIG. 14—ONE HUNDRED TON HYDRAULIC RIVETING PRESS
The pressure produced by this press causes the rivet to expand and completely fill the hole, making an absolutely rigid connection.

feet, is shown in Fig. 11. Pressed steel bed plates of the design shown in Fig. 8 can also be forged, up to six feet in length. Before pressing, all of these parts are blanked out as described above, this also being done in the press.

Aside from this forming of plates the press has another important function in the manufacture of forged parts by the piercing or squirting method. A small frame ring eight to twelve inches in diameter is shown in its finished form in Fig. 12. This piece is squirted from a solid block of steel, that is, the steel block is heated and placed in a cylindrical die, then by exerting a very high pressure in the center of the block, the material is forced up uniformly all around and, of course, to the exact diameters determined by the size of the dies. These rings are squirted about a foot high and then sawed apart to give the proper width of the individual ring.

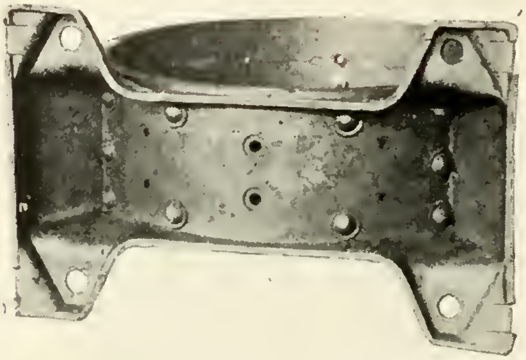

FIG. 15—BOTTOM VIEW OF FRAME AND FEET
Note the large rivet heads and their location, chosen to secure maximum leverage.

New cases where this press and especially this squirting method can be used to good advantage, present themselves constantly. A commutator bush in its rough forged and finished shape is shown in Fig. 13. It is made by the same method as the small frame ring just described, by piercing a solid steel block. This process has opened up entire new fields of manufacture, for not only is it possible to obtain an absolutely sound and dense material, vastly superior to the steel casting heretofore used for parts which are required to stand severe strains, but this new process is also in most cases more economical. It would tax the capacity of the best moulding machine operated by the fastest moulder to compete with this press, which forms a large commutator bush sleeve with a single squeeze by the move of a lever.

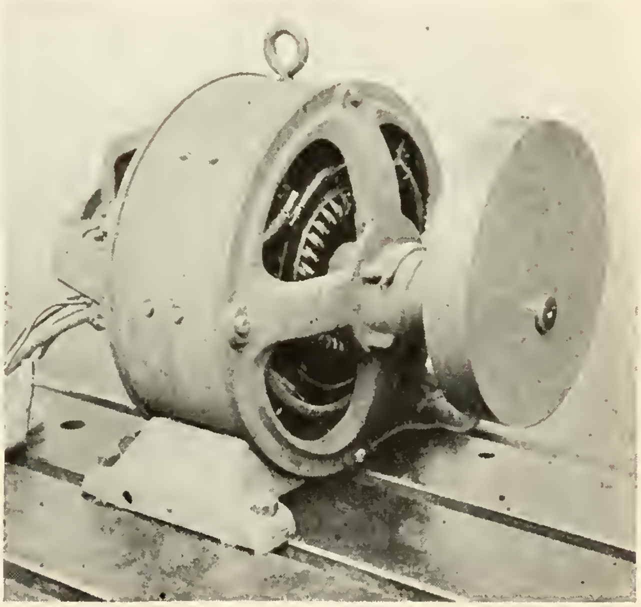

FIG. 16—ECCENTRIC LOAD TEST WITH WEIGHT MOUNTED DIRECTLY ON THE SHAFT OF A 30 HORSE-POWER, 230 VOLT MOTOR
The eccentric weight was 262 lbs. and the motor was run at speeds from 80 to 300 r.p.m.

The pressed steel foot shown in Figs. 6 and 10 is secured to the rolled steel frame ring by heavy rivets driven on a 100 ton hydraulic riveting press shown in Fig. 14. The frame rings are brought under the press on a carriage which is adjustable for different frame diameters and raised or lowered by compressed air so that the pressure does not come on the carriage. The pressure

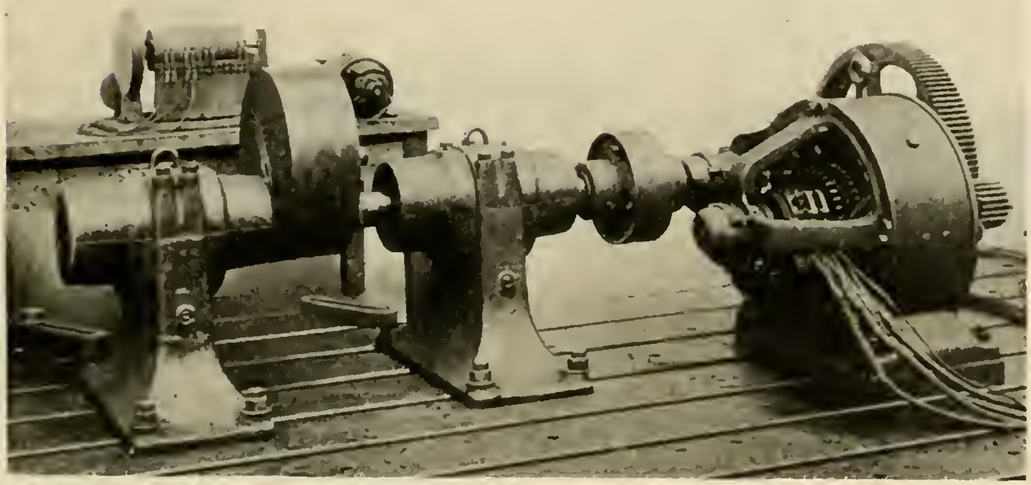

FIG. 17—ECCENTRIC LOAD TEST ON 15 HORSE-POWER, 230 VOLT, 850 R.P.M. MOTOR, GEARED TO A COUNTER-SHAFT

The eccentric weighs 750 lbs., 550 lbs. being unbalanced.

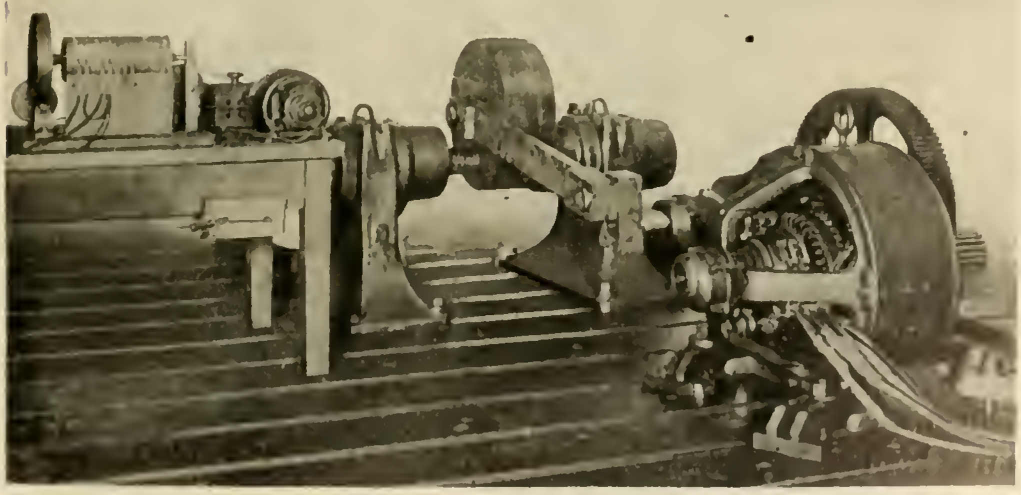

FIG. 18—OSCILLATOR TEST

The crank arm on the counter-shaft was connected through a driving rod to an eccentric weight of 925 lbs. so that the rotation of the crank arm would oscillate the eccentric weight. Average load on the motor, 110 percent full load. No damage was done to the motor by any of these tests.

exerted on the rivet can be varied to suit the size of the rivet. In every case the rivet fills the hole completely and has a large head, insuring a perfect riveted joint which not only has great mechanical strength but also eliminates all vibration at any speed for which the motor may be built.

A bottom view of a foot riveted to the frame is shown in Fig. 15 and gives a good idea of location and size of these rivets. Rivets are used every day under conditions demanding the utmost reliability under severe stress, such as bridge work, building construction, locomotives and boliers, and exhaustive tests have also been made regarding the most suitable material and methods for this particular application. Numerous running tests of the severest nature and continued for over two years have established the fact that strains many times in excess of anything that may occur under severe service conditions, are safely transmitted through frame and foot without any deteriorating effect on the riveted joint made by this high pressure riveter.

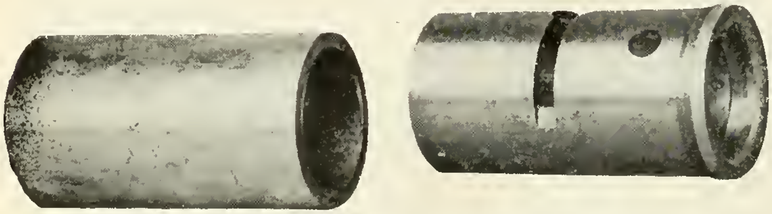

FIG. 19—STEEL SHELL BEARING, BABBIT LINED

The bearing shell, shown at the left, is drawn from steel tube.

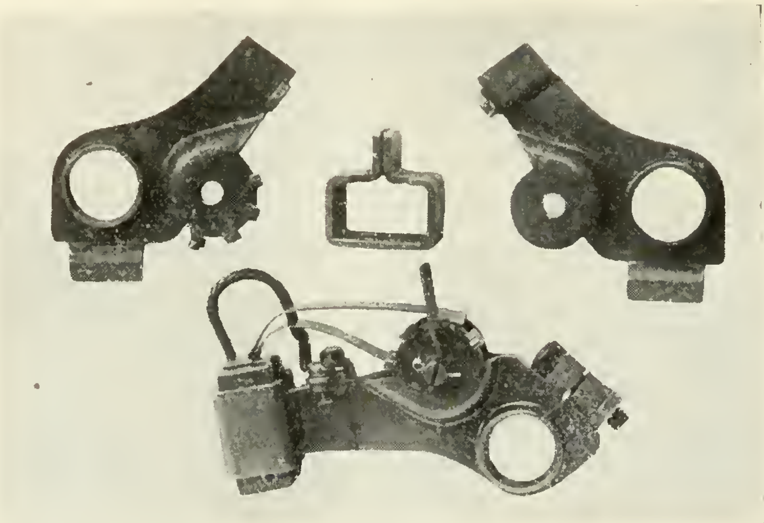

FIG. 20—PRESSED BRASS OR STEEL BRUSH HOLDER AND PARTS

Some photographs of these endurance tests are shown in Figs. 16, 17, and 18. Fig. 17 shows one of the motors back geared to a heavy eccentric weight and reversing every 12 seconds. This test was continued for a year and a half, day and night, and showed no effects on any part of the motor. In Fig. 16 the eccentric weight is mounted directly on the motor shaft, tending to produce a strong rocking motion and severe strain on bearings and frame construction. The oscillator test in Fig. 18, though still more severe, also failed to have any effect on the motor aside from normal wear of brushes and commutator. This test is arranged so that the eccentric weight does not make a complete revolution but oscillates both ways from the vertical center line. During the several months run most of the auxiliary parts broke in turn, driving rods, counter-shafts and their bearings had to be replaced, but no parts of the motor.

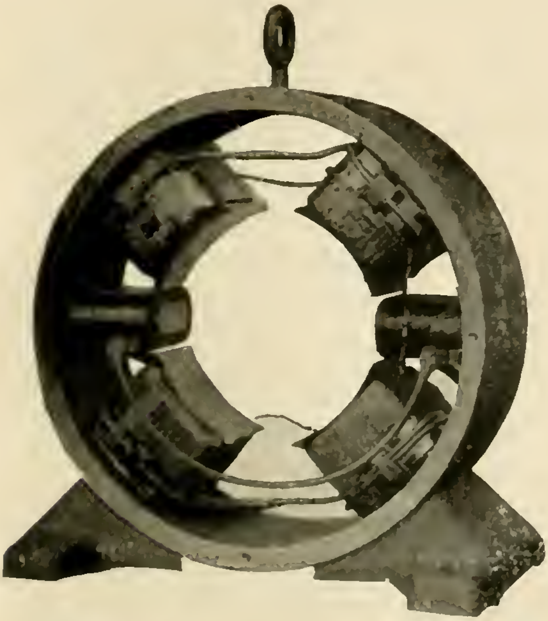

FIG. 21—FINISHED FRAME WITH FIELD COILS IN POSITION

One of the purposes of these tests was to give a thorough test to the type of bearing used on these motors, which may be briefly described in this connection, being of a somewhat novel design. It is shown in Fig. 19 and consists of a solid steel shell lined with babbitt. This shell is obtained by drawing steel tubing through a die on the draw bench in eight or ten foot lengths until the proper diameter and wall thickness are obtained. A bearing of this type is both light and rigid and has met with remarkable success in operation since 1907.

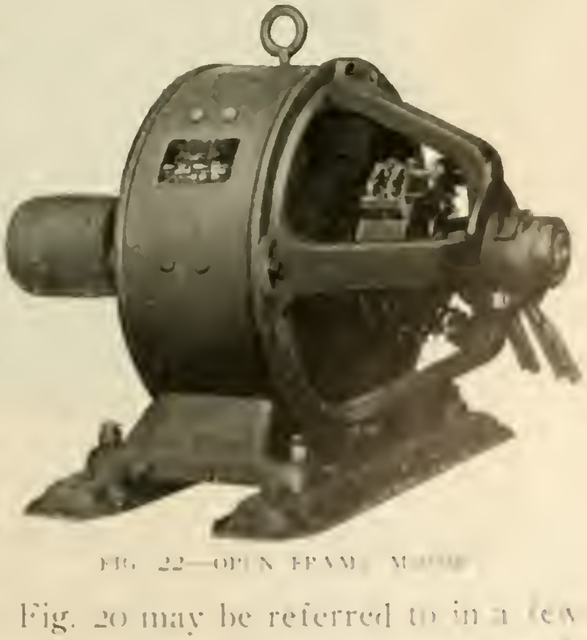

FIG. 22—OPEN FRAME MOTOR

As related in a way to the pressed steel work used on these motors and forming the subject of this article, the pressed brush holder shown in Fig. 20 may be referred to in a few words. It is formed from heavy sheet metal, the halves and brush holder boxes being riveted together. Instead of riveting these halves they are in some cases welded on a spot welding machine, making a still simpler manufacturing process and still more substantial holders.

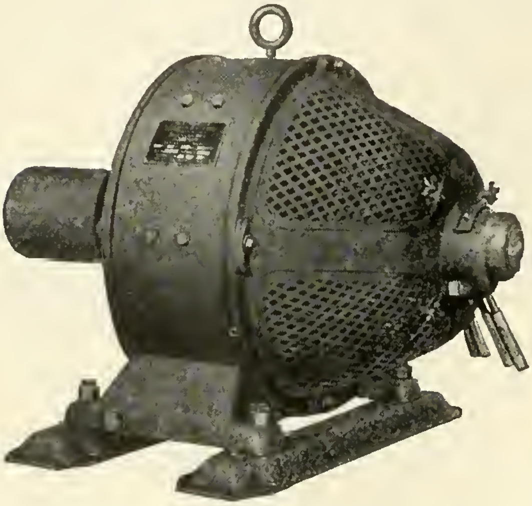

FIG. 23—PARTIALLY ENCLOSED MOTOR

Finished motors of this type in their different modifications, are shown in Figs. 21, 22, 23 and 24. During the last year and a half these motors have established for themselves a reputation for remarkable performance and general operating characteristics. Their light weight makes them especially suited for wall or ceiling mounting, while the exceptionally rugged construction adapts them for the severest service. Although the mechanical stiffness has been increased over some of the previous types of industrial motors, it has been the aim to avoid all unnecessary bulk in the inactive materials by using the most advanced manufacturing methods and to take advantage of any economies so made by liberal proportions and proper distribution of the active materials, securing thereby high efficiencies and excellent commutating characteristics.

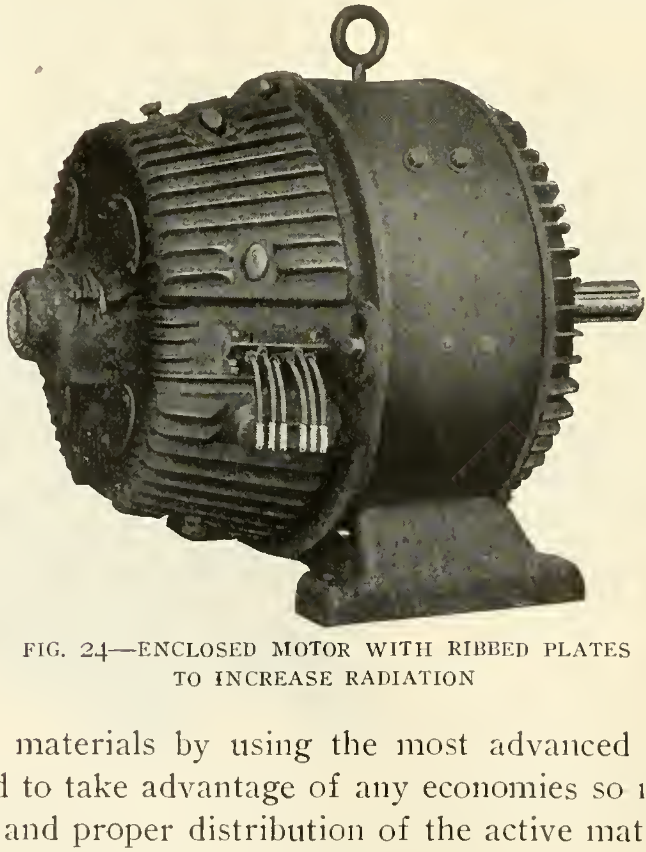

FIG. 24—ENCLOSED MOTOR WITH RIBBED PLATES
TO INCREASE RADIATION

LUMBERING BY ELECTRICITY IN THE NORTHWEST

IRA E. CHURCH,
Chief Engineer, Potlatch Lumber Company, Elk River, Idaho

UNTIL a very few years ago lumbermen looked askance at the proposal to drive planing mills electrically; they dismissed the subject of an electrically driven saw mill as absurd; and an electric logging donkey was unheard of. Yet all three are to-day in successful operation and are meeting with much favor.

To the lumber men in the Northwest has been given the opportunity to try out the application of electricity under the most favorable circumstances. In the East and in the Middle West the majority of the lumber mills were built before the general adoption of electric drive, and to operate these mills electrically would mean the throwing away of line shafting, belts and pulleys and substituting the electric motors and wires. In the states of Washington and Idaho the mills are of more recent construction, and it has consequently been possible to design them from the start for either system at approximately the same initial cost.

Heretofore the high first cost has been the main objection to electric drive, and there were few arguments in favor of the use of motors which were of sufficient importance to offset this first cost. With an abundance of fuel in the form of sawdust and shavings, for which there was no ready market, economy of power has been of no particular consequence. Saw mills of the older type were more or less open, damp and dirty, and conditions were usually far from ideal for the operation of motors. Of the arguments advanced in favor of the electric drive only one or two took into account the question of dollars and cents. Greater flexibility, a cleaner mill and less floor space required for the machinery were not as attractive arguments as a lower operating and maintenance cost. These last two items have now been proven to be of greater value than was at first anticipated. For instance, one mill which started up with the number of mechanics necessary for a steam-driven mill, including three millwrights, three helpers, a belt man and three oilers, was able, after the mill had been run a short time, to reduce this crew to one millwright, one helper and two oilers. The up-keep of the three electric mills, as specifically discussed in this article, is surprisingly low—not over ten to twenty percent of that of a steam mill of equivalent capacity.

THE MODERN BAND SAW MILL

In the older types of saw mills, circular saws were used, and are still retained in some sections, but with improvements in quality of steel and better methods of brazing came the change to the use of band saws. The advantage of the band saw lies mainly in the narrower cut. A circular saw cuts from one-quarter to five-sixteenths inch from each board, while a band saw will waste only about one-eighth of an inch. There is thus a saving of about twelve percent in sawing one inch boards. In a day's cut of 100 000 feet in logs the band saw would save about 12 000 feet of lumber, which would be wasted by the circular saw.

In a modern mill there will be found one or more head band saws, each, with its accessory apparatus, forming a unit, so whether a mill has one saw or four the progress of a single log will be the same. Mills which operate two or more head saws usually run them at different constant speeds in order to facilitate the cutting of the hardest and softest timbers. This necessitates operating the motors at a speed suitable for the average conditions. For a maximum output the saws should run at a speed depending upon the hardness of the logs, and this condition can only be secured by the use of a wound secondary motor. The control may to advantage permit a twenty percent speed reduction from full load in steps of approximately two percent. This is especially advantageous in those sections where the cold weather freezes the sap in the logs, as the speed of the saws should then be less than in the summer months.

FIG. I—GENERAL VIEW OF BUILDINGS AND YARDS
Elk River Mill of the Potlatch Lumber Company

A log passes through the mill in a process which is essentially e same regardless of the location of the mill and the type of lum-r. The logs are usually started from a mill pond, into which they e dumped from cars, wagons or sleds, or floated from a stream. A an with a pike pole steers a log into a trough, or "slip," with a othed chain, called a "bull chain," running on the bottom. The ll chain takes the log to the second floor of the mill. If the log too long for the lumber desired or for the carriage of the band w mill, it is first cut to the desired length with a cut-off saw, which ay be either a drag, circular or chain saw. It is then rolled onto e log deck and from there to the carriage, where it is held in place

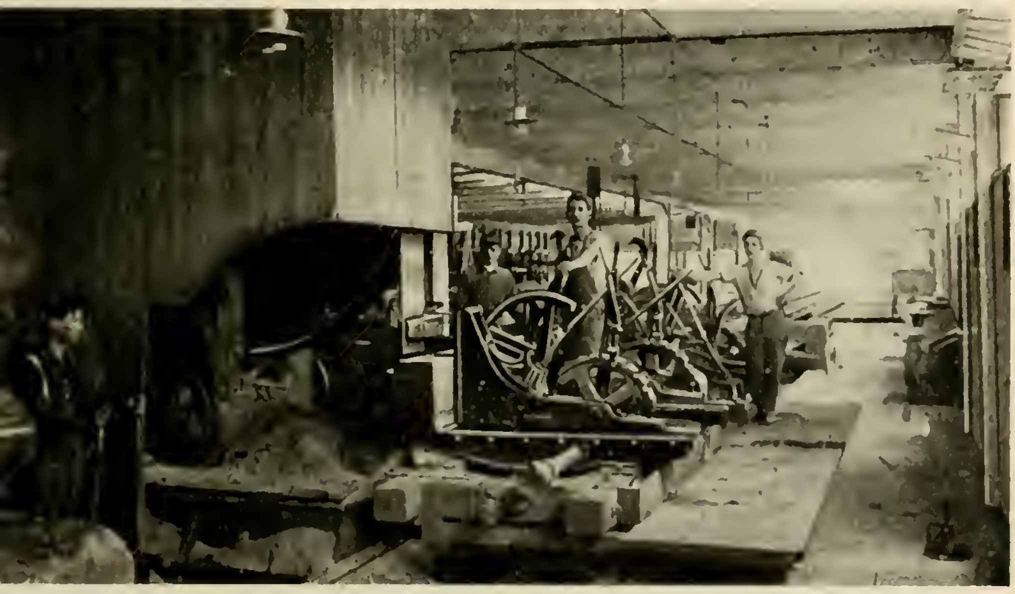

FIG. 2—EIGHT FOOT BAND MILL DRIVEN BY A 150 HORSE-POWER WOUND SECONDARY, 580 R.P.M. INDUCTION MOTOR*

The motor is belted to the mill from the floor below. The mill runs at 5 r.p.m., giving a cutting speed of 8650 feet per minute.

levers, as shown in Fig. 2. The carriage is actuated by either steam or compressed air cylinder and conveys the log past the w, which rips off an outer slab. This slab, which is waste material, conveyed over live rolls to about the center of the mill, where it "kicked" off on to the chain conveyor and carried through a set circular saws called the slasher, Fig. 5, which cut it into four foot ngths. These shorter pieces are then dropped onto a chain con-yor running through the lath mill. Here the pieces which are itable for making lath are sorted out, and the rest are put through a "hog", in which toothed wheels break it into smaller pieces, suitable for the boilers, or they are dumped on to another conveyor and taken to the burner.

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*The photographs shown in Figs. 2, 5 and 6 were not taken at Elk ver; all the other figures are views in and around Elk River, Idaho

Returning to the log on the carriage, a board is next taken off, which follows the slab for a short distance, and is then "kicked" on to a chain conveyor and taken to the edger. This machine has four adjustable circular saws, and the edgerman sets them to trim off the bark edge of the board, and if desired, to rip it into narrower pieces. A set of rolls behind the edger conveys the board and edgings past a sorter who throws the edgings and undesirable boards onto the lath mill conveyor, while the good lumber passes on to the trimmer, into which it is fed by a set of parallel tooth chains.

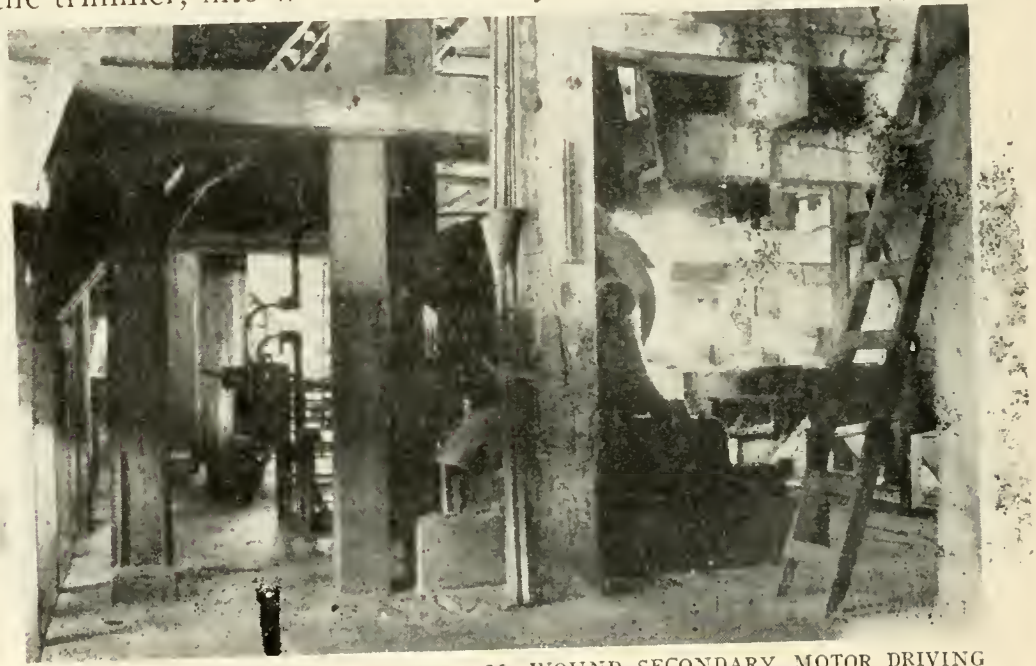


FIG. 3—200 HORSE-POWER, 900 R.P.M. WOUND SECONDARY MOTOR DRIVING BAND SAW.

At the Elk River Mill of the Potlatch Lumber Company.

A man in a cage over the trimmer has under his control a number of circular saws, set close together, as shown in Fig. 6, one or more of which may be lowered at a time. These saws trim the edges of the boards square and cut them into any desired lengths. All pieces of four feet or less in length drop into the lath mill conveyor, while the good boards are conveyed past the sorters and graders, by whom they are directed into that portion of the yards devoted to drying and storing that particular kind and size of lumber.

On the first floor, under the saws, are chain-belt conveyors which receive the sawdust and also the broken up slabs from the "hog" and convey them to the boiler room, where both sawdust and slabs drop through chutes into the furnaces.

THE SELECTION OF MOTORS

In the vicinity of Spokane, Wash., are three band saw mills using individual motor drive, each mill having from twenty to forty-ive motors. These mills are located at Deer Park, Wash., Ione, Wash., and Elk River, Idaho. In the majority of instances the notors for similar work are substantially the same, the Elk River Mill having a tendency towards wound secondary motors, while nore of the squirrel cage type are used at the Ione Mill. These atter have in some cases a lower rating for the same work, but the vound secondary motors have the advantage of low starting current, adjustable speed and the ability to start under a heavy load. The squirrel cage motors, on the other hand, require less attention and have no slip-rings and brushes to get dirty or clogged up with saw dust. Squirrel cage motors could be used exclusively by using clutches to throw on the load in those cases where the load to be started exceeds the starting torque of the motor, but this is not generally advisable. Most motor applications are quite severe and require a heavy frame and bearings and a high starting torque. On he band saws especially, if a squirrel cage motor is used it should have high resistance end rings; in most cases wound rotors with control suitable for at least twenty percent drop in speed are recommended, as this control not only allows varying speeds at full load and permits utilization of the fly-wheel effect of the band mill wheels, but also gives very excellent starting characteristics without rawing excessive current from the line.

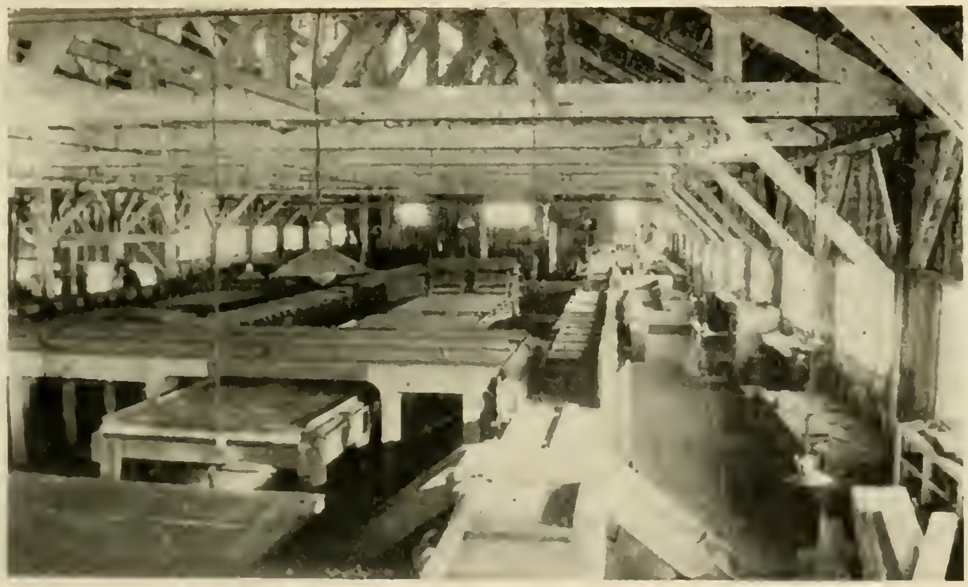


FIG. 4—SAWING FLOOR
Looking toward band saws. Live rolls in the foreground.

In the Elk River Mill the "bull chain" is run by a 40 horse-power slip-ring type induction motor, while at Ione, where the chain is longer, a 50 horse-power squirrel cage motor is in use. For sawing logs to the desired length before they reach the band saws, the Elk River Mill uses a chain saw driven by a ten horse-power squirrel cage motor, as shown in Fig. 8. This saw is made up of links with saw teeth on one side, and runs over two sprocket wheels, something like a bicycle chain. It is a very fast worker, and has the further advantage of causing no such vibration to the mill as does a reciprocating drag saw. The band saws in the Elk River Mill are belted to 200 horse-power wound secondary motors, while at Ione 150 horse-power squirrel cage motors are used. Since the Elk River Mill is the newest and largest, and all the mills are in general quite similar, a description of the motor applications in this one mill only will be given.

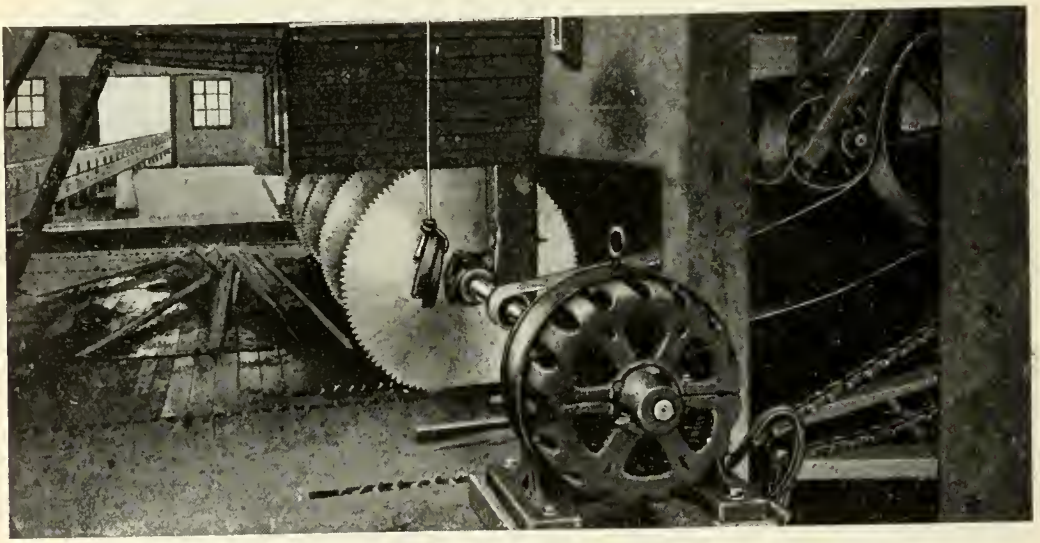


FIG. 5—FORTY-SIX INCH SLASHERS DRIVEN BY A 30 HORSE-POWER, 850 R.P.M. SQUIRREL-CAGE MOTOR

The motor is directly connected to the shaft carrying five 46-inch circular saws. The transfer chains to the slashers are driven by a belt from the motor shaft. The 30 horse-power motor handles the heaviest stock satisfactorily.

ELK RIVER SAW MILL

In this mill there are forty-five motors varying in size from one to 200 horse-power. Practically every machine is individually driven and wherever possible the motors are direct connected. For the chain conveyors and live rolls, where the speed is very low, back geared motors are commonly used, with chain drive, as shown in Fig. 9. These motors have a speed of 600 to 900 r.p.m. with a gear ratio of one to six and a sprocket ratio of one to four and one to eight. A few of them have been changed to belt connection with the reduction gearing separate from the motor, as it was found that in some cases the heavy chain pull would spring the shaft. In other cases the change was made because of the excessive vibration transmitted to the motor by the chain. These motors are subjected to very severe operating conditions, especially those having chain drive where there is no chance for momentary relief, as is the case where the motor is belt connected. The load frequently changes from almost no load to full load or a severe overload almost instantly, such as when a large slab is suddenly dropped on to a conveyor running light.

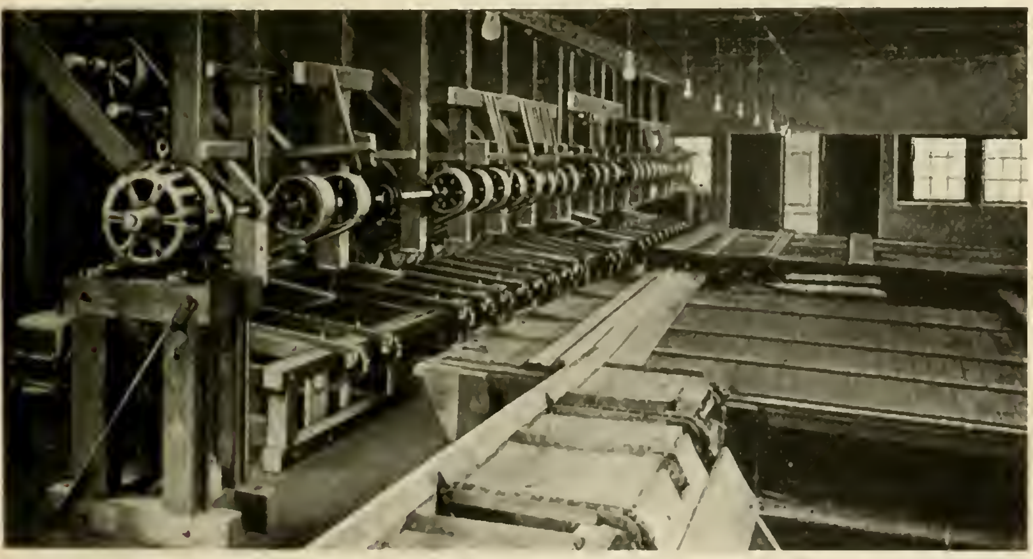


FIG. 6—TWENTY-FOUR INCH TRIMMERS DRIVEN BY A 30 HORSE-POWER, 850 R.P. M. SQUIRREL-CAGE MOTOR

There are two line shafts, each driving eleven 24-in. saws. Belt drive nakes the friction load higher than on slashers of same general type.

The motors are all placed as near as possible to the work, some n the floor, some on upright timbers, some bottom side up on the eiling, and others in wooden frames hung from the ceiling.

The band mill motors are on the lower floor and are belted to ie lower shaft of the band mill, which is just under the second oor. The edger motors are direct connected, the rotor being iounted on one end of the edger shaft. The inertia of the rotor id saws in this case is very small and it has been suggested that a y-wheel be added or that the motor be placed down stairs with a y-wheel and belted to the edger shaft above. This would allow a smaller motor to be used with less danger of stalling. There is considerable time lost and often much hard work connected with getting a board out of the edger that is stuck because the motor stopped. Hence there is a tendency to screw down the circuit breaker to a point where it will never trip, with consequent danger of stalling and burning out the motor.

The trimmer and slasher motors are connected by flexible couplings to a short line shaft from which belts run to the individual saws. In the lath mill the bolter and lath machine are both direct connected. In the filing room the emery wheels, lap-grinders, forges and automatic band filers are individually driven with motors of two and three horse-power capacity.

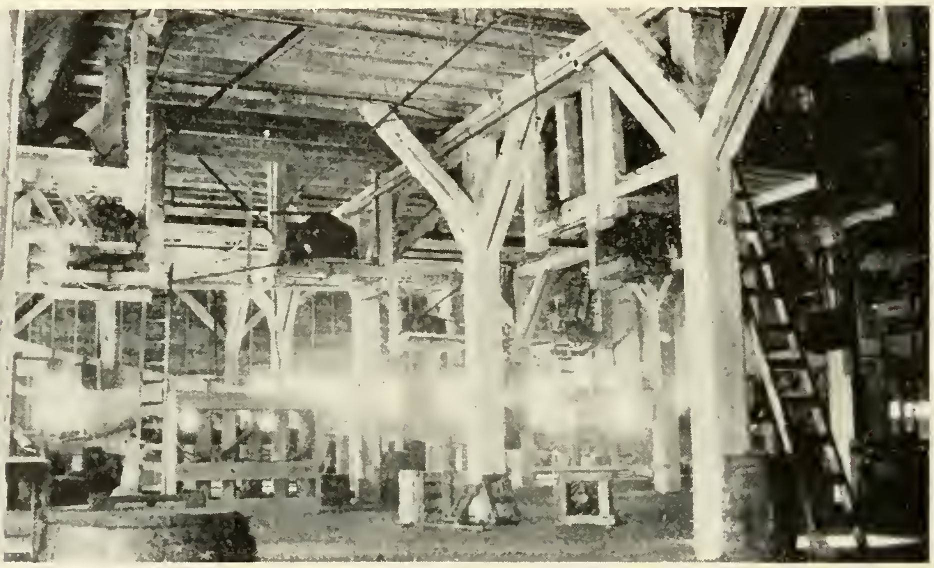


FIG. 7—GENERAL VIEW OF LOWER FLOOR, ELK RIVER PLANT, POTLATCH LUMBER CO.

Showing suspension of motors driving rolls and chains for floor above.

POWER PLANT

As previously stated, the fuel for the furnaces consists of sawdust and broken slabs. The boilers are of the return tubular type with two banks of two and two banks of three boilers each, making ten in all. They furnish steam for the steam turbines and dry kiln, for the carriage feed in the mill, the "niggers" which turn the logs over, and the "kickers" which shove the slabs and boards onto and off the various conveyors. The engine room contains two turbo-generator units totaling 1 625 k.v.a. They are designed for 600 volts, three phase, 60 cycles, but as the motors are all built for 550 volts the generators are run at that voltage.

THE PLANING MILL

The planing mill has twelve planers, designated as profilers, surfacers and matchers, two moulders, two rip saws, one cut-off saw, a siding saw and a band re-saw. There are two exhaust fans and a charger to take care of the shavings. The motors are all of the squirrel cage type with the exception of that driving the band re-saw, which has a wound rotor and slip-rings for resistance starting. This equipment differs from most others in that 75 horse-power motors are used on all the planers instead of the 40 and 50 horse-power motors ordinarily used. They were chosen of ample size to overcome the trouble generally experienced in starting the planers, especially on cold winter mornings.

THE DREDGE

The mill pond was made by widening the channel of Elk River. This stream carries considerable sediment, which settles in the pond, so a floating dredge was built to keep this cleaned out and also for enlarging the pond and filling in low places around the mill and yard. Current is supplied to the dredge at 2 200 volts and is stepped down to 440 volts for the motors. There is a 35 horse-power motor belted to a centrifugal pump and a 30 horse-power motor belted to a line shaft from which are operated the air pump, the moving mechanism and the digging apparatus.

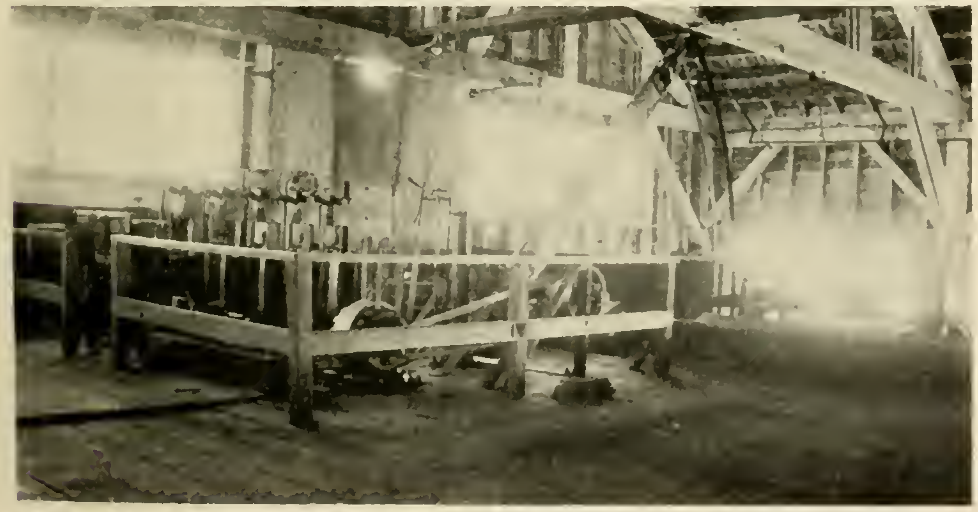


FIG. 8—CHAIN CUT-OFF SAW BELTED TO A TEN HORSE-POWER, 1 200 R.P.M., SQUIRREL-CAGE MOTOR

YARD LOCOMOTIVES

The lumber about the yard is all handled with storage battery locomotives, each having two ten horse-power, 120 volt motors geared to the trucks. The batteries used are the new Eidson type and will run the locomotives all day, but a boost is generally given them during the noon hour. The up-keep on the batteries and motor has been surprisingly low, considering the severe service and inexperienced operators that often have to be depended upon.

LOGGING DONKEYS

Adjoining the power house is a 600 k.v.a. transformer station stepping the bus-bar voltage up to 11 000 volts for a four mile transmission line into the woods (Fig. 10), where are working at present two logging donkeys with 150 horse-power, three-phase, 550 volt motors of the wound rotor type. Each donkey is connected to a portable sub-station of 200 k.v.a. capacity by an armoured three-wire cable, as shown in Fig. 11. Each donkey also has a 75 horse-power motor which runs an air pump furnishing compressed air for the clutches and brakes of the line drums. These logging donkeys have what is known as the sky-line equipment. In this system a cable is run into the woods and a carriage is run on this cable which is hung on supports about thirty feet from the ground. The logs are brought in by fastening one end to this carriage and letting the other end take care of itself. Sometimes it is dragging on the ground, while at other times it may be three or four hundred feet in the air as it crosses a canyon. From one to four logs are

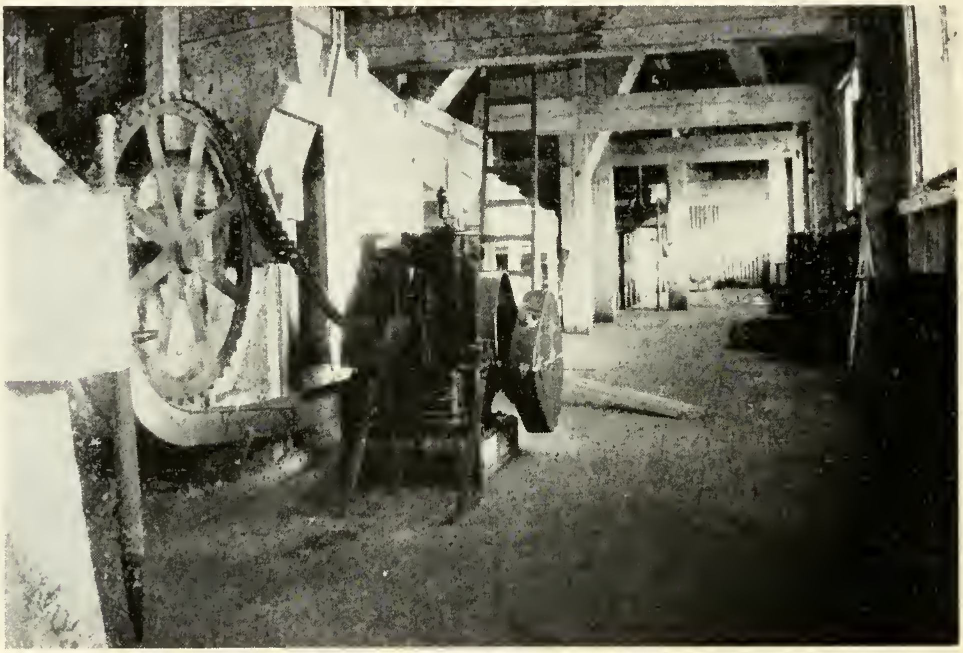


FIG. 9—SAWDUST CONVEYOR CHAIN DRIVEN BY A TEN HORSE-POWER, 600 R.P.M. BACK-GEARED WOUND SECONDARY MOTOR

taken at a time, according to the size, and the speed is very much higher than with the ground line donkeys, which drag their loads on the ground. The service on these donkeys is very severe and the motor must be of specially rugged construction. An electromagnetic brake is provided on one end of the motor and connected across two of the motor leads so that while the motor is running the brake is released, but sets immediately when the power is off the motor. The average load of one of these donkeys for the day is about 60 horse-power, with an average power-factor below 50 percent, that is, a recording wattmeter registers about 400 kw-hr. for ten hours. An indicating wattmeter registers all the way from 30 to 400 kw. with quite long intervals of rest at times.

MOTOR LOAD FACTORS

Upon making a wattmeter study of the various motors in use

FIG. 10—11 000 VOLT TRANSMISSION LINE THROUGH THE WOODS TO AN ELECTRIC DONKEY

at Elk River, it was found that most of them were running much below their rated capacity most of the time, so the power factor at the power house is quite low—about sixty percent. On the other hand, all of the motors are called upon at times to deliver more than their rated capacity for short intervals. For instance, on starting up the conveyors and rolls on a cold morning the motors have to deliver more than their rated horse-power for some little time. Then at times the rolls get clogged, and an accumulation of slabs and sawdust are dumped into a conveyor at one time. The band saws, edgers and slashers, of course, have quite a varied intermittent load. Although the average load of the eight-foot edger is less

TABLE I—LIST OF MOTOR APPLICATIONS IN ELK RIVER MILL

SAW MILL

Machine	Horse Power	Kind of Rotor	Method of Connection	Speed, R.P.M.
Band Saws (3)	200 each	Wound	Belted	900
Edger (6 Ft.)	50	Squirrel Cage	Direct	1800
Edger (8 Ft.)	75	" "	"	"
Slasher	40	" "	"	600
Trimmer	30	" "	"	720
Hog	40	" "	"	720
Bull Chain	40	Wound	Belted	900
Chain Saw	10	Squirrel Cage	"	1200
Slasher Conveyor	15	Wound	"	600
Burner "	25	"	"	1200
Slab "	15	"	"	600
Cross "	15	"	"	"
Sawdust " (4)	10 each	"	Back Geared, Chain Drive	"
Boiler Room Conv.	15	"	Belted	"
" " "	10	"	"	"
Slasher Chains	15	"	Back Geared, Belted	"
Trimmer " (2)	15 each	"	" " "	"
Log Deck " (3)	7.5 "	"	Back Geared, Chain Drive	900
Band Mill Rolls (3)	7.5 & 5	"	Back Geared, Chain Drive	900
Timber Chains & Rolls	25	Squirrel Cage	Back Geared, Belted	1200
Incline Chains	10	" "	Belted	1200

PLANING MILL

Machine	Horse Power	Kind of Rotor	Method of Connection	Speed, R.P.M.
Band Resaw	50	Wound	Direct	600
Planers (10)	75	Squirrel Cage	Belted	1200
Inside Moulder	30	" "	"	1200
Outside Moulder	10	" "	"	1200
Rip Saws (2)	5	" "	"	1200
Cut-Off Saw	5	" "	"	1200
Exhaust Fans (2)	50	" "	Direct	514
Charger	50	" "	Belted	900

MACHINE SHOP

Machine	Horse Power	Kind of Rotor	Method of Connection	Speed, R.P.M.
Line Shafts (3)	7.5	Squirrel Cage	Belted	1200

FORGE ROOM

Machine	Horse Power	Kind of Rotor	Method of Connection	Speed, R.P.M.
Blower	3	Squirrel Cage	Belted	1200

DREDGE

Machine	Horse Power	Kind of Rotor	Method of Connection	Speed, R.P.M.
Pump	35	Squirrel Cage	Belted	1200
Line Shaft	30	" "	"	"

ELECTRIC DONKEYS

Machine	Horse Power	Kind of Rotor	Method of Connection	Speed, R.P.M.
Line Drums	150	Wound Rotor	Geared	900
Air Compressor	7.5	Squirrel Cage	"	1200

than 40 horse-power, the 75 horse-power motor used is sometimes stalled. In the planing mill the 75 horse-power motors could be replaced by 50 horse-power motors. The only question involved is whether the lower cost and better power-factor will over balance the possibility of burn-outs and delays caused by warming up a planer by running it awhile with part of the belts removed.

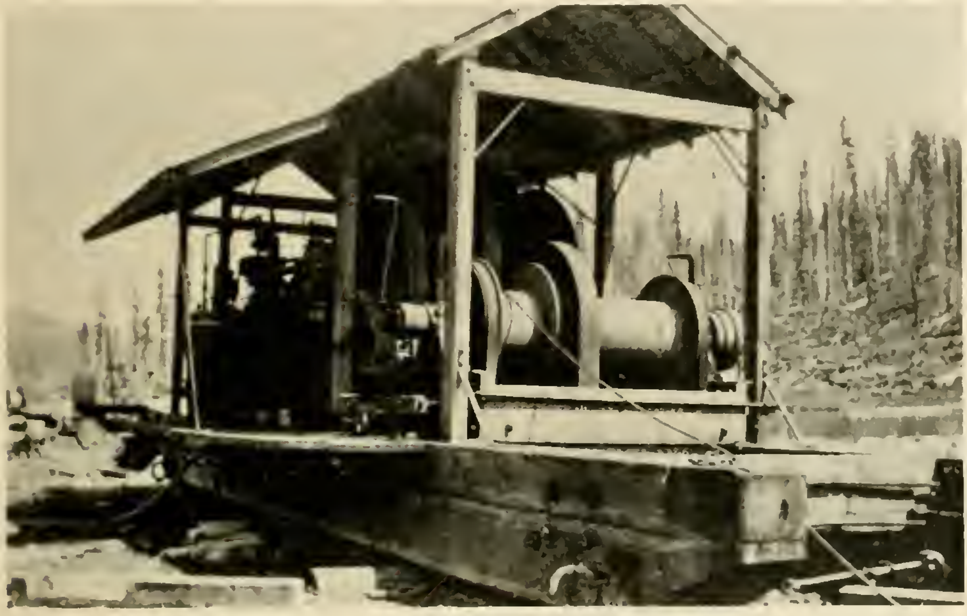


FIG. 11—ELECTRIC LOGGING DONKEY IN THE FOREST

Drum Controller at the left; line drums in foreground; ammeter and circuit breaker at rear; armored cable from transformers at left.

The operation of the Elk River Mill has been very satisfactory in the two years it has been running; this is due partly to the ample size of the motors used and to the care given the electrical equipment, as well as the care used in laying out the mill and selection of the equipment.

MOTOR-DRIVEN CENTRIFUGAL PUMPS

E. C. WAYNE

Commercial Engineer, The Goulds Manufacturing Co.

ALTHOUGH the first centrifugal pump was manufactured in this country nearly one hundred years ago, it is only within the past decade that engineers have recognized its peculiar fitness for certain conditions. Both on account of the rapidity with which the use of centrifugal pumps has increased and because of the characteristics of such a pump, which differ widely from those of any other pumping unit, the necessary data for the correct application of a centrifugal pump has not been generally available.

CAPACITY AND HEAD

Those who have used pumps of the reciprocating type exclusively are apt to think of capacity in terms of speed, regardless of the head against which the pump operates. In the case of a centrifugal pump there is an intimate relationship between the two, and in making an application of a motor driven centrifugal pump the following inherent characteristics of the apparatus must be taken into account:—

1—With constant head the capacity will vary as the square of the speed.
2—With constant speed the capacity will vary inversely as the square of the head.
3—The head is proportional to the square of the speed, the volume being proportional to the speed.

The above statements are not absolutely correct in that they do not take into consideration the friction losses in the pump, which, of course, vary according to the design. However, the results obtained by the application of these laws are accurate enough for most requirements. From this it is evident that there should be a definite understanding as to whether constant head and capacity are desired, and if not, what range must be accommodated. It is also important to know approximately the percentage of time the pump will be operating under each capacity. For example:—Suppose that a capacity of 400 to 600 gallons per minute against a 50 foot head is desired. The problem that confronts the manufacturer is to select an equipment which will have an overall efficiency as high as possible. There are two ways to meet the conditions:—First, reducing the speed to obtain the lower capacity in accordance with characteristic *1* mentioned above, and second, maintaining constant speed and throttling the discharge, which really amounts to building up the head with consequent reduction in capacity, in accordance with characteristic *2*.

Speed variation involves additional expense in so far as the electrical end of the equipment is concerned and should not be recommended unless an analysis shows that the use of this method insures lower operating expense. The only way to arrive at such cost is to know the length of time the pump is operating under each capacity, determine the power required in the case of each method, and from this data the relative cost for current can be calculated.

Where the conditions call for constant capacity at a given head the pump can be operated at constant speed and the only point which requires special consideration is the possibility of reduction of head to such an extent as to seriously overload the motor. As the head is reduced the capacity of the pump increases, the amount of increase depending upon the design of the pump. Consequently, the manufacturer who is furnishing the pump should be requested to advise the horse-power required at the shaft when the apparatus is operating against the minimum head. With this information it will be possible to select a motor of such capacity that it cannot be seriously overloaded. Due to the advances which have recently

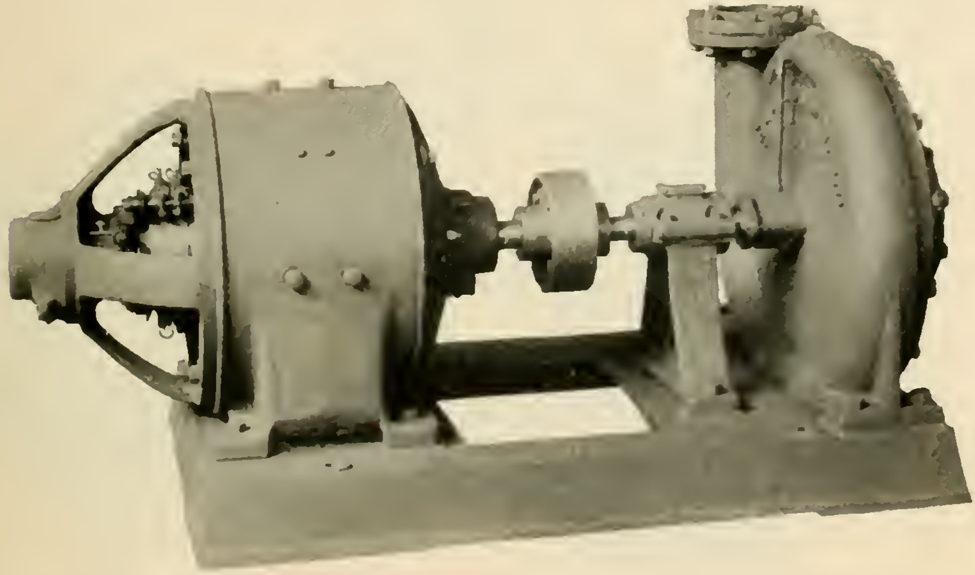


FIG. 1—SINGLE STAGE, SINGLE SIDE SUCTION, HORIZONTAL SHAFT, OPEN TYPE IMPELLER CENTRIFUGAL PUMP

This pump is adapted to installations where the head does not exceed 100 feet. On account of the large open water passages, it is extensively used for handling sewage and for stock pumping in pulp and paper mills. For the same reason it has a large field in irrigation, mining and contracting work, as the water in such cases is apt to contain considerable sand and grit. A great many of these pumps are also used for general water supply and booster service.

been made in the design of centrifugal pumping machinery, it is now possible to obtain apparatus equipped with a non-overload impeller. With this feature the capacity at the minimum head is so restricted that the motor overload cannot exceed 25 percent, which any well known commercial machine will stand for two hours without serious heating. It should be definitely understood, however, that all centrifugal pumps do not have this characteristic, and for this reason the question deserves special attention prior to the selection of a pump and motor to drive it. The centrifugal is essentially a velocity pump and in many instances even those who have used a pump of this type do not fully appreciate how sensitive it is to speed changes. It will, therefore, be well to outline just what factors should be considered in determining the head, for without a clear understanding of this point a motor of proper capacity and speed cannot be selected.

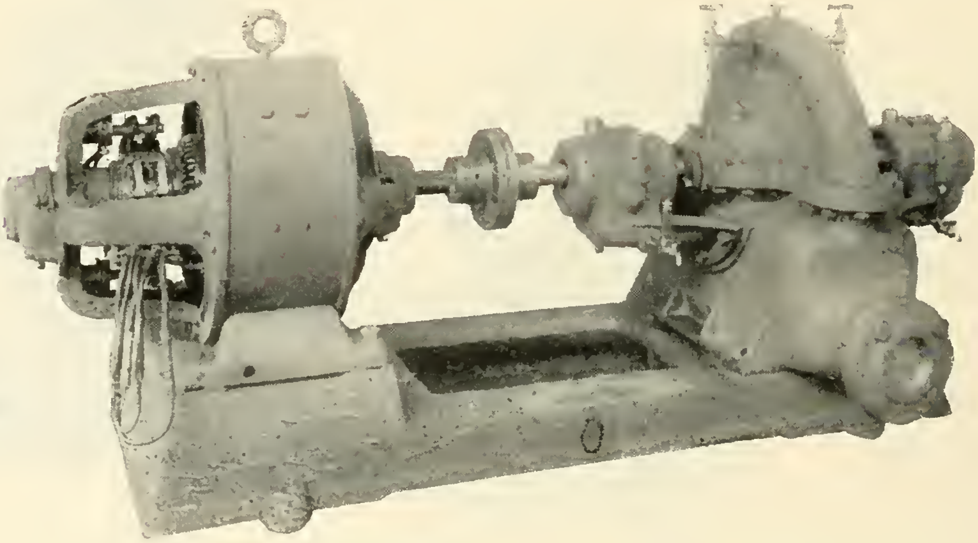


FIG. 2—SINGLE STAGE, DOUBLE SUCTION, HORIZONTAL SHAFT, ENCLOSED IMPELLER CENTRIFUGAL PUMP

This outfit is for installations where the head is not greater than 150 to 160 feet. The majority of these pumps are used for general water supply, hot water circulation in heating systems, irrigating plants, booster and mine service.

For example, a manufacturer built a centrifugal fire pump to be driven by a direct-current motor supplied by the purchaser. The apparatus was designed to deliver 500 gallons per minute against 100 lbs. pressure and the pump builders specified a motor speed of 1 700 r.p.m. Upon testing the equipment it was found to deliver 390 gallons per minute against 100 lbs. pressure. Investigation showed that the motor was operating at only 1 525 r.p.m., or about 10 percent below that specified. After the outfit had run a considerable length of time, however, the capacity came up to the requirements and upon further checking the motor speed it was found to be 1 700, as originally called for. The case was somewhat unusual and was, therefore, called to the attention of the electrical manufacturers. A study on their part showed that there was a wide variation in motor speed when running cold and hot. They did not realize, however, in shipping the motor, that the difference would make such a marked reduction in the performance of the pump. The motor manufacturer overcame the difficulty by supplying a field rheostat for increasing the speed of the motor when running cold. After the motor became heated the rheostat was, of course, cut out.

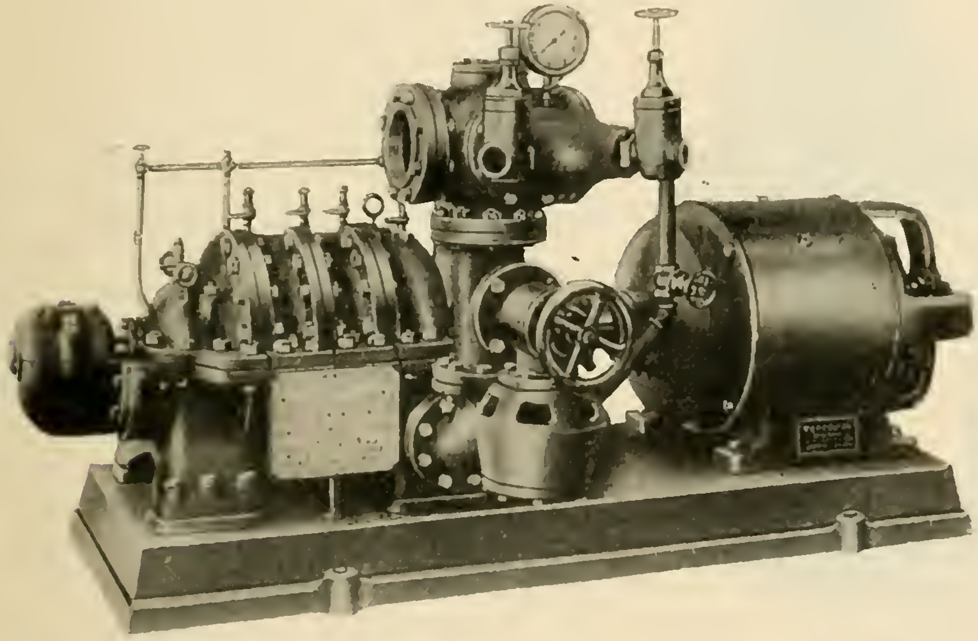


FIG. 3—MULTI-STAGE UNDERWRITERS CENTRIFUGAL FIRE PUMP

Designed primarily for supplying water under high pressure to fire service mains. When intended for this work the pump is equipped with special fittings. This type of pump is also largely used without the special fittings for general water supply, where conditions call for higher pressure than can be obtained with a single stage pump.

If a permanent shunt had been supplied the speed of the motor would have been nearly 1 900 r.p.m. when heated and the machine would have been overloaded approximately 33 percent. This will illustrate the importance of using a motor in accordance with the pump builders' recommendations.

Special emphasis should be placed on the increase in head due to friction in the piping. It sometimes happens that a purchaser measures the static head and entirely neglects any allowance for friction. With a reciprocating pump such oversight would not be so apt to cause difficulty provided sufficient power were available. On the other hand the capacity of the centrifugal would be much less than desired. This brings up another interesting situation resulting from the advertising on the part of electrical concerns advocating individual motor drive for many installations. Whereas formerly line shafting was used almost entirely for operating machine tools, pumps, etc., the tendency to-day is to use a separate motor for each machine. With shaft drive many people have no idea of the power required by the various machines, whereas with the new arrangement it does not take them long to find out if they have made an improper motor application.

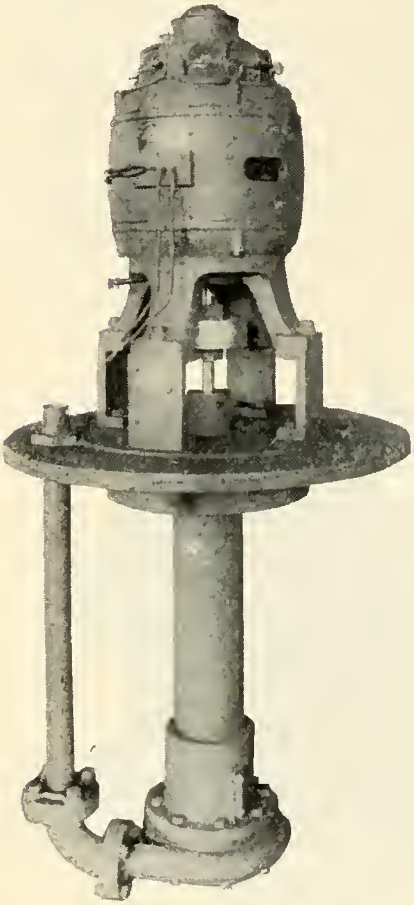


FIG. 4—VERTICAL CENTRIFUGAL SUMP PUMP

Directly connected to vertical electric motor. A great many of these pumps are used for draining basements, handling domestic sewage and for similar work, where the liquid to be pumped accumulates in a pit or sump. The motor is usually controlled automatically by a starting device actuated by a float in the sump.

DETERMINATION OF TOTAL HEAD

The total head against which a centrifugal pump operates is made up of the sum of four factors, viz., suction lift, discharge head, friction head (due to losses in pipe line) and velocity head. Suction lift is the vertical distance from the level of the water to be pumped to the center line of the pump. If the water level is above the center line of the pump, the pump is then said to operate under a suction head and the distance must be subtracted from the sum of the remaining factors. The discharge head is the vertical distance between the center line of the pump and the level to which the water is elevated. The friction head is determined by referring to tables which give the losses in pipe lines and elbows for different sizes and capacities. The velocity head *H* in feet is determined by solving for *H* in the equation.

$H = \frac{V^2}{64.4}$ where V is the velocity of the water at the discharge nozzle of the pump in feet per second. In all cases where possible, a sketch should be furnished showing the length and size of the pipe line which will be used with the centrifugal pumping unit, as well as the number and character of the bends and other pipe fittings. With this data the pump manufacturer can readily estimate the horse-power and speed required at the pump shaft. It is safe to say that the great majority of troubles experienced with centrifugal pumps have been due to an incorrect understanding of the importance attached to the question of head. Electrical salesmen and central station solicitors will, therefore, be doing the best kind of missionary work if they strive to "drive this point home" whenever they hear that one of their customers is considering a motor-driven centrifugal pump installation.

POWER REQUIREMENTS

The driving power required by a centrifugal pump will vary directly with the product of the capacity and head. It will be of assistance in this connection to consider a concrete proposition, the conditions of which are as follows:

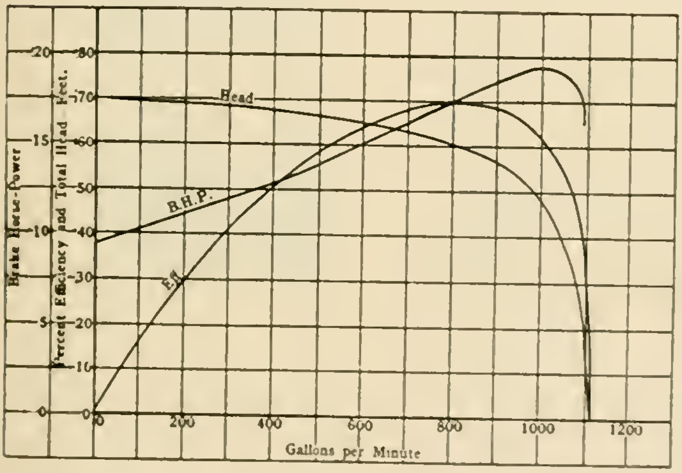


FIG. 5—TYPICAL CENTRIFUGAL PUMP CHARACTERISTIC CURVES

Six-inch, single-stage, double-action pump. Average r. p. m. 1740. Showing the large increase in output and in horse-power required of the motor for a slight decrease in head.

Capacity, 800 gallons per minute; static suction, 5 feet; suction pipe, 25 feet long, 6 inches diameter, one 90 degree bend; static discharge head, 34 feet; discharge pipe, 300 feet long, 6 inches diameter, one 90 degree bend; current, 60 cycle, three phase, 220 volts.

The total static head is 39 feet. Adding 21 feet for friction and velocity (determined from hand-book tables, using the pipe dimensions as a basis) the total net head amounts to 60 feet. The pump manufacturer finds that a 6-inch single stage, double suction pump will fill the requirements very nicely and guarantees an efficiency of 70 percent. The horse-power is then obtained by the use of the following well known formula:—Brake horse-power $= \frac{\text{Gal. per min.} \times \text{head}}{3960 \times \text{eff}}$ $= 17.3$. From this it is evident that a 20 horse-power motor should be used, as it is the nearest commercial size.

In order to operate against the head specified the impeller of the pump must have a proper peripheral speed. It is, therefore, a question of using a large diameter, slow-speed impeller or a small diameter high-speed design. Pump manufacturers usually figure on the highest speeds possible in the case of direct motor driven units, as this reduces the cost of both machines and also cuts down the floor space required. Furthermore, the pump efficiency is better with the small diameter impeller due to reduction in friction losses. In the present instance, therefore, a motor having a synchronous speed of 1 800 r.p.m. would work out to good advantage. The performance of this pump is well illustrated by the curves in Fig. 5, which show variation in head, horse-power, capacity and efficiency obtained by throttling, it being understood that a constant speed motor is driving the pump. This curve clearly shows the maximum load to which the motor can be subjected. The curves in Fig. 6 show the performance of the same pump at different speeds.

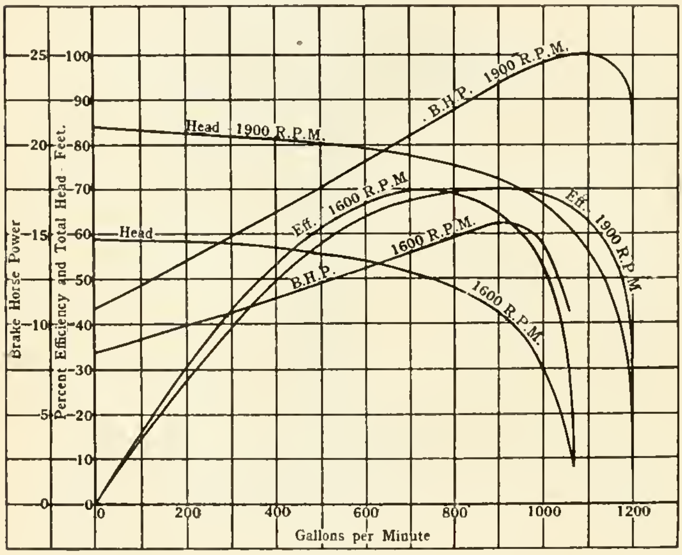


FIG. 6—CHARACTERISTIC CURVES OF SAME PUMP AT 1 600 AND 1 900 R. P. M.

Nothing has been said in the above discussion about the power required from the moment of starting up to the time the pump is running under normal conditions of capacity and head. Assuming that the pump has been primed and is running at full-load speed, with discharge valve closed, which is the ordinary procedure, the power required is 40 to 50 percent of that necessary at the same speed with the pump working under rated conditions. This will be evident upon noting the point of no discharge or shut-off pressure on the curves.

Generally speaking, if no account is taken of the static friction of the bearings and the inertia of the moving parts, no power is required to start a centrifugal pump. After starting, the power required increases as the cube of the speed until full speed is obtained. Therefore, if the above pump is started up with the discharge valve closed, the power will build up to 9.5 horse-power as the cube of

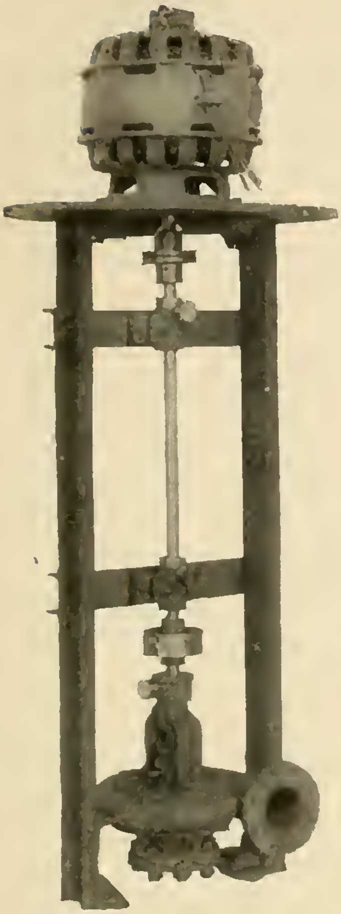


FIG. 7 — SINGLE-STAGE, VERTICAL CENTRIFUGAL PUMP

Directly connected to vertical motor, the two units being securely mounted in a substantial structural steel frame. This insures correct alignment and makes a very satisfactory equipment. Outfits of this sort are largely used for sewage disposal systems, where the material is screened prior to entering the pump. There is also a wide field for such pumps in irrigating work, where a well constitutes the source of supply and the water level is so far below the surface of the ground as to preclude the possibility of using a horizontal pump.

the speed. If the same pump is started with the valve in the discharge line open, the power will increase from zero to 17.3 horse-power as the cube of the speed.

TYPES OF MOTORS

Direct Current—In most direct-current installations a shunt wound motor is used. A machine of this sort with standard hand starter is very satisfactory where the capacity and head are constant. When the equipment is to work under varying head and capacity, it is possible in many instances to obtain proper speed variation by means of a field rheostat, as usually an increase of 15 percent above normal can be effected. The pump, of course, is so designed that the desired capacity and maximum head are obtained at the maximum possible motor speed, otherwise there would be a possibility of overloading the driving unit. Where a greater speed variation is necessary a variable speed motor should be used, together with suitable non-reversing controller. In certain installations where the voltage fluctuates widely it is well to figure on compound-wound motors owing to their tendency to maintain constant speed.

ALTERNATING-CURRENT MOTORS

The great majority of electrically driven outfits are arranged for alternating current. Where the requirements call for constant speed the squirrel cage induction motor with hand starter is very satisfactory, except in certain instances where the rush of current at starting is detrimental. In such cases a slip ring type of motor may be used, as it is possible to start up slowly by means of suitable controller and resistance. This type of motor is also used where the conditions require a variable speed machine.

Synchronous motors are being specified in a few instances where the power-factor of the circuit is low. In applying these motors the feature requiring most attention is "pull-in-torque," that is, the torque which the motor develops when it reaches maximum obtainable speed just before the field is excited, the speed at this time being only slightly below synchronism. As heretofore stated, with the discharge valve closed, pump primed and operating at about normal speed, the motor must develop a pull-in-torque of approximately 40 to 50 percent full load in order that it may come up to synchronism. At slow speeds this torque cannot be obtained except by large expensive motors and by drawing an exceedingly heavy line current, but with moderate and high speed motors it can be secured without excessive line current. In every instance where synchronous motor drive is being considered there should be a definite understanding between the pump builder, electrical manufacturer and purchaser as to the power required at starting. The design of some synchronous motors is such that, at the instant of pulling into synchronism, only about 15 percent of normal torque is developed. With a motor of this type the only method of starting is to have the pump empty. After full speed is reached the pump is primed. Starting in this manner, however, cannot be considered satisfactory, because modern high grade small clearance contrifugal pumps should not be run "dry," i. e., with no water in them. Another scheme is to start the outfit with a smaller independent motor, but in view of the satisfactory self-starting synchronous motors which are now on the market, this is not finding favor.

STANDARD RATING FOR ELECTRICAL APPARATUS

A RESUME OF THE PAPERS APPEARING IN THE PROCEEDINGS OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS FOR FEBRUARY

CHAS. F. SCOTT

FORTY-TWO papers on one topic, containing nearly six hundred pages, make the February proceedings of the American Institute of Electrical Engineers a notable volume. The character of the papers—recording results of experience or data from special tests, discussing methods of measurement and the results of tests and proposive new methods of rating and testing electrical apparatus—as well as the joint authorship of the first paper by Messrs. Steinmetz and Lamme, indicate an active interest in an important matter. Furthermore, the papers are to be supplemented by discussion at the three-day Mid-winter meeting of the Institute, (intervening between the writing and the printing of this article) so that the Standards Committee may have the basis for a revision of the part of the Standardization Rules relating to the Rating of Electrical apparatus.

The essential features of this group of papers may be indicated thus:—

1.—Fixing certain safe temperatures at which experience shows that different classes of insulating materials may be operated with safety.

2.—A classification of the service conditions of motor operation and a description (with an A. I. E. E. inscription on the nameplate) of the capacity under each of these several conditions without reaching an injurious temperature.

3.—Discussion and tests of methods of measuring temperature.

4.—Discussion and tests on losses and their measurement.

5.—Miscellaneous: the sphere gap for measuring high e. m. f's; wave shape; cables; brush and commutator losses; regulation.

Among the papers dealing with rating, the two leading ones deal with "Temperature and Electrical Insulation" and with the "Method of Rating Electrical Apparatus" in which temperature is the principal determining element. More than one-third of the papers deal primarily with temperature and its measurement, while a still greater proportion deal with losses and their measurement. Losses and temperature, therefore, consume over 75 percent of the consideration given to rating.

Why so lively and sudden an activity in so seemingly simple and supposedly settled matters as the measurement of temperature and of power losses and the rating of electrical machinery? What in general terms, are the technical points involved in the present papers and what is the practical significance of proposed changes? What, we may even ask, is the Standards Committee and what is the function and authority of the Standardization Rules?

It is opportune to review the whole matter from a broader standpoint than the technical discussion of the papers themselves.

Origin of A. I. E. E. Standardization—Fifteen years ago, the January meeting of the Institute was devoted to a topical discussion on "The Standardization of Generators, Motors and Transformers." The discussion was opened by Mr. E. W. Rice, Jr., who said the chief object was a thorough discussion, after which the matter could be referred to a committee with instructions to consult with various interested parties and report its conclusions, with recommendations The initial point of view is indicated by condensed extracts from his remarks.

> "The advantages of establishing certain standard types and sizes of apparatus have been fully recognized. Such standard lines have been arbitrarily determined by each of the different manufacturing companies. Competition has tended to increase the number of standard sizes and the development of the industry has added enormously to the variety of the apparatus in use. The adoption of such standards has been one of the greatest factors in the phenomenal development of the industry in the United States. It has enabled our manufacturers to produce the standard lines selected at phenomenally low cost and has also resulted in an equally great improvement in quality. The chief beneficial effect of an agreement would be to limit the demand for special apparatus which may have to be manufactured by comparatively expensive and less perfect methods. The manufacturer, while undoubtedly animated by selfish motives in advocating standard apparatus where possible, is at the same time advocating the best interests of the industry as a whole.
>
> "Certain features of the subject could and should properly be considered by the Institute. I refer to the terms used to define certain characteristics and the methods of determining them; viz., 1—Definition of efficiency. 2—Heating limits and methods of determining them. 3—Regulation. 4—Sparking. 5—Insulation, methods of testing. 6—Rating. 7—Frequency."

It is interesting to note how nearly this original schedule has been followed. In commenting upon frequency it is remarked that "alternating current machinery is being built for frequencies of 25, 30, 33, 40, 50, 60, 66, 125 and 133 cycles in this country." The practical elimination of all but two of these indicates a progress toward which A. I. E. E. recommendations have materially contributed.

Dr. Kennelly, now chairman of the Standards Committee, said in the early discussion that "questions of what regulation should mean, what temperature elevation should mean and how it should be measured, what efficiency should mean, etc., are eminently practical and proper technical questions to be settled and defined by recommendation of the Institute. They would faciltate progress. But I should be inclined to regard with disfavor any attempt to standardize apparatus in any other way than by the process of evolution among business interests."

To Dr. Steinmetz the problem appeared to have "two different phases; one is standardizing the meaning of terms, and the other is standardizing the methods of tests."

The early interest is manifested by the fact that over a score took part in the discussion which was held simultaneously in New York and Chicago. A committee was appointed and has been in continuous existence; the first report issued in 1899 has had two principal revisions, in 1902 and 1907. A further revision is imminent.

Standardization Rules—There is no formal and specific statement of the scope and purpose of the rules, but an acquaintance with the working of the committee for several years indicates that its policy, in accord with the ideas developed in the discussion in 1898, is to present a scheme of good practice which may be accepted generally, thus insuring uniformity. In addition to definition of terms, the methods which have proved best by experience have been chosen and formulated—rarely have the rules presumed to direct the trend of future development.

The sanction, which the professional endorsement of the committee has given, has been generally accepted, and often the rules have been given greater weight than was intended by the committee. The rules have sometimes been regarded as having an absolute authority, or as covering a subject broadly and conclusively whereas the committee had simply endorsed what represented the best knowledge or practice then available. For instance, the table of sparking distances between needle points, originally submitted by Dr. Steinmetz, received the comment from him a few years ago that a re-determination of sparking distances was desirable in the light of new knowledge of high tension phenomena. Some have expressed surprise that special provision was not made in the insulation tests for transformers which were to have one terminal permanently grounded; but they overlooked this sentence:

"The voltages and other conditions of test which are recommended have been determined as reasonable and proper for the great majority of cases and are proposed for general adoption, except when specific reasons make a modification desirable."

It happened that a number of rules were drafted providing appropriate tests for various specific transformer connections, but it was found difficult to cover all cases, and it was deemed best to give general rules and leave specific cases to adjustment between the engineers who would have to do with the specifications of transformers which were large enough to render special tests of importance.

Past policy is indicated in the opening paragraph relative to definitions which say:

"The following definitions and classifications are intended to be practically descriptive and not scientifically rigid."

The Institute is a professional—not a commercial—body; it may well continue to limit itself to principles and to the sanction of what is at the time the best practice; its function is not to make commercial rules, but to recognize the engineering principles upon which commercial specifications may be based.

The Rating of Apparatus—The latest Webster says, "Rating—The normal (designed) or estimated value of some quantity, as power or speed in a machine or apparatus. Thus, a 10 horse-power motor run at 12 horse-power is run above its rating." Rating seems to be something quite simple and definite. But suppose a motor has lost its nameplate.

What tests would be necessary to determine a rating for it and to supply the nameplate data, such as volts, amperes, speed and horse-power? What are the practical limits to volts and amperes and speed and horse-power? These limits are primarily in the materials. A motor is essentially a combination of iron, copper and insulation. The volts depend largely upon the quality of the iron, the amperes upon the copper, the life of the insulation upon the resulting temperature to which it is subjected, and the speed is limited by mechanical strength. In no case is there a critical point or a definite physical limit, which fixes the commercial rating. It is no wonder that, in the early days before conferences were held and definitions and arbitrary limits were fixed, the ten horse-power motors of different manufacturers which had been "rated" according to the ideas of different designers, might differ widely in their actual capabilities. Even though ten horse-power motors of different brands may have corresponding electrical capabilities, new difficulties occur in applying the motors, for the "ten horse-power" required for the driving of a uniformly running ventilating fan, is quite different from the "ten horse-power" for an intermittent planer or an occasionally running saw.

The rating of electrical apparatus is, therefore, not so simple a matter as it may at first appear. As a first approximation, it is a simple matter to say that a motor is capable of delivering ten horse-power and can replace a ten horse-power engine. When refinements are considered, including the speed regulation, the efficiency, the overload capacity and the temperature, and when different motors are to be compared in these respects, then a much more accurate knowledge of the motor's capabilities is necessary. These refinements are a natural accompaniment of the closer adaptation of the motor to the duty it is to perform. Better materials and better knowledge and experience on the part of designers enable motors to be made lighter and cheaper and to meet definitely the requirements of a specific performance. Furthermore, the service to be performed by motors, in the matter of speed regulation and the like, is far more definite and exacting than in the old days when the motor simply replaced a little engine. Hence new materials, new ability in design and new service conditions all call for a more exacting definition of motor performance. The early rules contained no motor classification, but in 1907 it was proposed to classify motors according to their constant or variable speed characteristics. The new classification is based primarily not on the characteristic of the motor, but upon the service, and there are six proposed service ratings, three of which are termed continuous, and three short-time ratings, each being divided into constant service, continued periodic service and continued pulsating service. This distinction is significant as it indicates the general tendency to design and adapt electrical apparatus to meet the service to be performed. A service classification must necessarily be an arbitrary one, as there are no distinct and absolute divisions between the different classes. If each manufacturer were to establish his own arbitrary classifications and each consulting engineer devised new specifications, which may best meet his particular conditions, obvious confusion would follow. The suggestion is now made that these Institute classifications be recognized by all and that the name plates of machinery rated in accordance with the future rules of the Institute bear the inscription of the A. I. E. E.—a most excellent suggestion.

Electrical apparatus in operation may be said to have three responsibilities;—one to the central station which supplies the power; one to the customer, and one to itself. In a transformer, for example, the central station is concerned principally with the losses in the transformer. These are due primarily to the presence and quality of the iron. The user of the power is concerned mainly with the voltage or quality of the service which he receives; this is determined principally by the copper windings of the transformer. On the other hand, the transformer itself is concerned principally with its preservation, and this, in turn, depends very largely upon the third material of which it is composed, namely the insulation. The life of the insulation is in turn a function of the heat developed in the transformer and the facilities for the dissipation of that heat. Losses and temperature are, therefore, the factors of predominating importance in the cost of operation and in the life of the apparatus, whether it be transformer or generator or motor.

The fact that a third of the papers relate directly to temperature seems surprising. The simple statement that the temperature of an apparatus must not exceed 40 degrees C.

above the surrounding air is as simple and seemingly definite and satisfactory a specification as could be wished. On second thought one can see some difficulties in measuring the internal temperature of a rotating armature or of an inclosed transformer, but what could be simpler than the measurement of the adjacent air with a thermometer. Nevertheless, several papers are devoted to the measurement of the surrounding air, and it is shown that if the temperature of the air changes from time to time, while that of the apparatus changes slowly, a casual measurement may be very greatly in error, and it is difficult to prescribe just how to determine the mean or effective air temperature. On the other hand, one paper shows that the method of covering the bulb of an ordinary thermometer lying on a metal plate heated to about the permissible temperature of an armature may lead to differences of nearly ten degrees in the indication, while there may be nearly 20 degrees between the covered and uncovered bulb.

It is little less than startling to find that the temperature specification, upon which millions of kilowatts of electrical apparatus have been sold, is a matter of so great uncertainty and divergence of practice. The whole group of papers on losses and temperature indicate the new factors which appear when careful technical analysis is applied to what has been assumed to be simple and well established.

In the measurement of losses the input-output method is difficult to apply as slight errors in the measurement of either element may cause a large error in their difference. On the other hand the direct measurement of the losses usually assumes that the loss at full load is equal to the "stray power" plus loss at no load (less the copper losses) plus the I^2R losses at full-load. It is known that the stray power loss does not remain constant and that ordinary I^2R calculations do not include eddy current loss in the copper. This difference is called the "load" loss. Half a dozen or more papers deal with these load losses and show how small they may be in well designed machines and how large they may be sometimes.

The character of the papers is noteworthy; in general, they are based upon experience or tests. They are primarily quantitative papers in that they give the actual results which have been attained either through years of experience in the testing of many machines, or in special tests conducted to provide data for presentation at this time. The authors of these papers have been preparing this material for many months, and it is understood that thousands of dollars have been expended in securing data for the use of the Institute Standardization Committee. In running over the list of contributions it will be found that the majority are connected with manufacturing companies. This again indicates that the manufacturing concerns are not merely designing and making apparatus, but by the contributions of their engineers are aiding in a substantial manner in maintaining the professional and technical standing of the American Institute of Electrical Engineers.

The purpose of standardization is not to fix definitely limits which may retard progress, but to determine what is best in what has been done and make it the basis for the future. This is a continuous process, so that revision by modification and addition in the light of accumulating experience is the normal and healthy condition of standardization rules in a rapidly progressing profession.

Begining at the Electrical Congress in St. Louis in 1904 an international movement for standardization has been under way. Our Standards Committee and the U. S. National Committee of the International Electrotechnical Commission are working in close conjunction. Rating is a matter of active international interest at the present time.

POWER REQUIREMENTS OF FANS, BLOWERS AND EXHAUSTERS

C. W. DRAKE

THE use of air in industrial work as a carrier of heat, obnoxious gases, finely divided solids, etc., has become more common than many imagine. In many of our new office buildings the air is filtered, passed over either steam or refrigerating coils to obtain the correct temperature and is then forced to all parts of the building. Enormous volumes of air are forced through coal mines to carry away the dangerous gases. In the planing mill the shavings and sawdust are drawn from the tool as cut and carried by a blast of air to the cyclone over the boiler or storage bin. The work of the air now being done, it is exhausted quietly to the atmosphere, while the wood particles fall into the hopper below. In a paper mill, about two tons of water are evaporated over the paper machine for every ton of paper produced, and air is about the only medium which can absorb this moisture and carry it away from the room.

Every time a certain volume of air is moved, a certain definite amount of power is required, regardless of the use to which the air is put, but depending upon the velocity with which it is moved and the resistance in its path. There is no simple rule for solving all problems, but each should be considered by itself and all conditions taken into account. In the following pages an outline is given of the various types of apparatus available for moving air and a brief description of the characteristics, uses and limitations of each. Fans, blowers, and exhausters are classified in three distinct groups or divisions according to the mechanical construction and principles involved, namely;—centrifugal, disc, and positive. Any type of rotary air or gas-handling device can be either a blower or an exhauster depending on whether the device is used to drive the gas into a container or to draw it out. There are certain slight mechanical modifications in some types depending on whether the fan is used for blowing or exhausting, but in most types they are mechanically identical and can be used for either purpose.

Centrifugal Fans are those in which the gases are drawn in axially and discharged tangentially. Mechanically this type consists of a number of rotating vanes which are generally enclosed in a housing so as to direct the blast. A centrifugal blower usually has two axial inlets and a centrifugal exhauster only one. Centrifugal fans are made in various forms for a great variety of purposes, among which the following are prominent:—Heating and ventilation of buildings and mines, drying kilns, mechanical draft, forge and cupola blowers, exhaustion of foul or poisonous gases, conveying systems for gases and for light materials such as cotton or wool fibers, tea, grain, powdered coal, etc., and collecting systems for planing-mill refuse or the grit from tumbling barrels and emery grinders or in any application where large volumes of air or gases are handled at moderate pressure. When acid fumes are handled the blast-wheel and housings must be made of non-corrosive metal. When used for conveying or collecting systems the blast-wheel, piping, and housings must be made of heavier metal than when air only is handled and particularly so if the blast contains grit or emery dust.

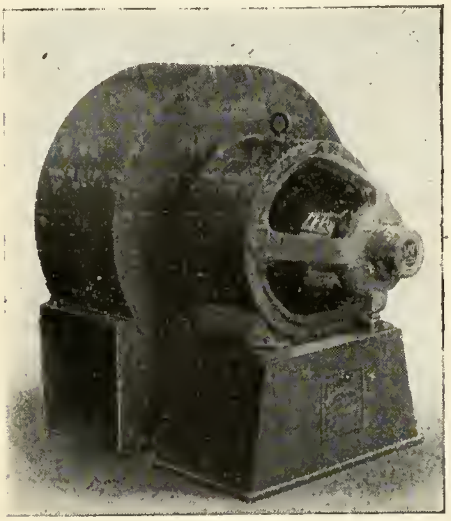


FIG. 1—STEEL-PLATE CENTRIFUGAL FAN

The centrifugal type includes steel plate fans, "Sirocco" fans, multivane fans, volume and pressure blowers, and cone fans, the latter being substantially a steel plate fan without housings. The name "Steel Plate" is used by all manufacturers to indicate that the housing is made of steel plate riveted or bolted to structural steel shapes, as shown in Fig. 1. These fans and exhausters are adapted to a wide range of service, being especially suitable for heating and ventilation of buildings and mines, drying systems for brick and lumber, and exhaust systems handling fine material, gases, etc. The amount of air to be handled determines the size of fan required, and the kind of material conveyed by the air determines the air velocity and the type of wheel. Air velocities of about 3 500 feet per minute are customary for planing mill refuse; for light shavings a somewhat lower velocity can be used; green saw dust from a band saw mill will require from 4 000 to 4 500 feet per minute.

The word *"Sirocco"* when applied to a fan or blower is a registered trademark, used by The American Blower Company, to designate a type of centrifugal fan having a patented runner, for which performances considerable better than those of the ordinary blower are claimed. This type of fan, shown in Fig. 2, is much used for heating and ventilation, drying systems, mechanical draft and the like, but is not applicable to conveying systems handling solid matter. The housing is usually of steel plate, although in the smaller sizes it is of cast iron and the larger sizes are frequently installed with frame or masonry housings.

Cast iron volume blowers of the type shown in Fig. 3 are applicable for supplying air under pressure to furnaces burning coal or coke for heating plates, rivets, etc., for blowing powdered fuel into rotary kilns or other furnaces and for blowing forge fires which have large tuyeres but do not require over 4 ounces pressure. They are also especially adapted for supplying mechanical draft for boilers. As an exhauster this type of fan is best adapted for handling gritty dust such as comes from emery wheels and tumbling barrels which would quickly cut and destroy a sheet-steel housing. They are also well adapted for exhausting smoke from forge fires, steam from cooking vats and general ventilation, within their capacity. The feature of this type from which it obtains its name is that the housing is of cast iron. These housings are so made that any position of the outlet can be obtained by removing the bolts and revolving the circular plate which supports the bearings

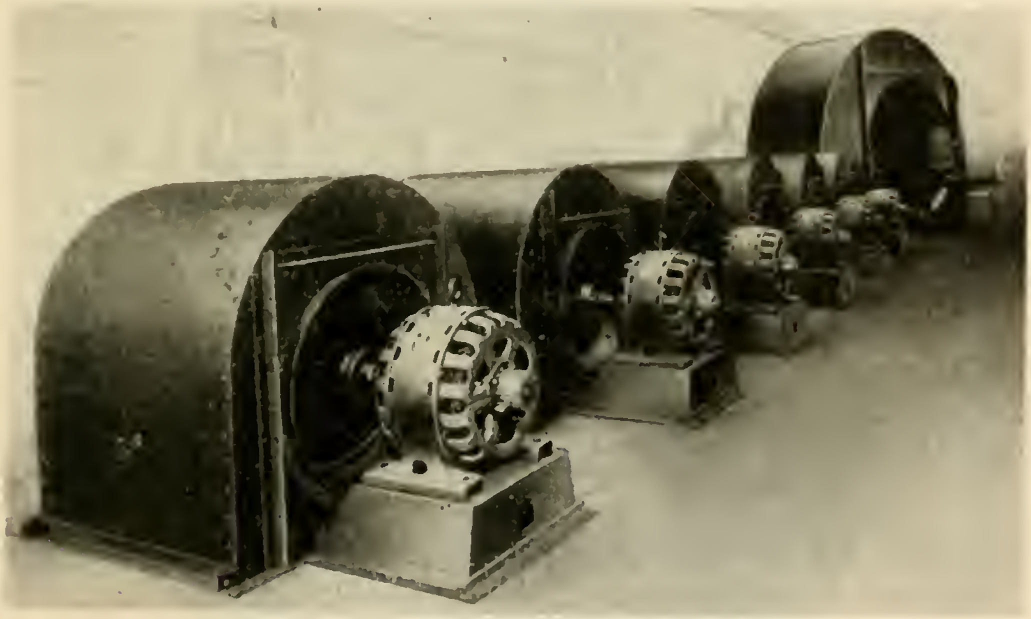


FIG. 2 —GROUP OF "SIROCCO" FANS

Steel pressure blowers of the type shown in Fig. 4 are especially adapted to services requiring considerable volume at several ounces pressure and are mostly used for forge and cupola blowing and for supplying air blast to oil, gas and coal-fired furnaces. The range of this type overlaps somewhat the range of the positive pressure blowers, and within the limits of pressure obtainable, it is used for about the same purposes.

Disc or Propeller Fans are those in which the gases are drawn in axially and discharged axially. This type is too well known to require description; the blades are made in a number of shapes depending on the service and the ideas of the manufacturer. A large percentage of these fans are driven by direct-connected electric motors. They are made in a large number of sizes. Disc fans are applicable only where comparatively large volumes of air or gas are to be handled at very low pressures. The blades are ordinarily similar to those shown in Fig. 5, but fans of this type are also frequently made with special or overlapping blades, for which improved operating conditions and high efficiency are claimed, the exact shape depending on the service required and the ideas of the manufacturers. This type of fan is widely used for the ventilation of buildings, the smaller sizes being most generally used as exhausters, drawing out vitiated air, vapors and fumes, and the larger sizes being used in connection with heating systems, for blowing air through heating coils into a chamber for distribution throughout the building. The

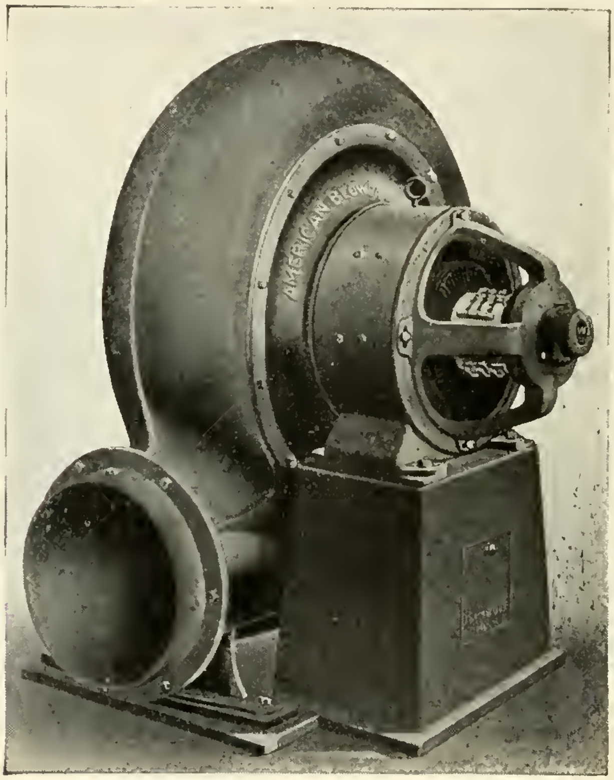


FIG. 3—CAST IRON VOLUME BLOWER

larger sizes are in common use for mine ventilation. One modification which is used for cooling tower service, is made especially heavy and is called a "Cooling Tower Fan."

Positive Pressure Blowers are rotary air pumps which deliver approximately a constant volume of air per revolution regardless of the pressure, hence the name "positive." This type is made in a large range of sizes and usually consists of two revolving elements as shown in Fig. 6 between which a certain volume of gas is entrapped and transferred from the inlet to the outlet with only a small amount of leakage. Since the two impellers must maintain a constant angular relation they are geared together so as to rotate in opposite directions and ordinarily are geared to the driving motor as shown in Fig. 7. They are separated from each other and from the casing by a small but constant clearance, which allows a slight leakage. Positive pressure blowers are used mainly for pumping illuminating gases, furnishing blast for forges, cupolas and smelters, and for other purposes requiring a given volume of gas at pressures from about twelve ounces to eight pounds per square inch. For pressures higher than this the reciprocating pump is a much more efficient device.

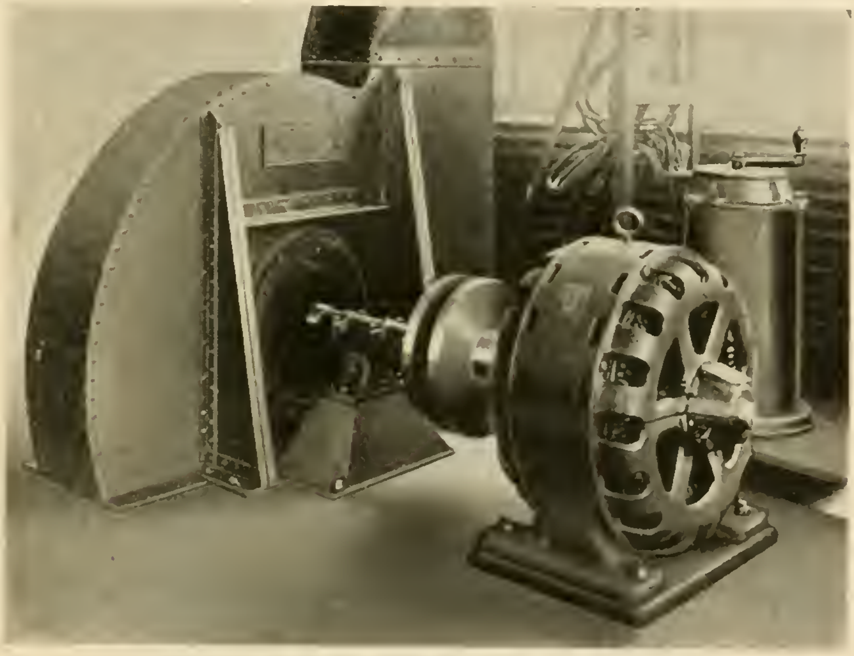


FIG. 4—STEEL PRESSURE BLOWER

It is evident from the foregoing that the different types are not strictly competitive, but that each occupies a field wherein it is supreme. It is true, however, that the centrifugal type does overlap the range of the disc type on the one side and that of the positive pressure type on the other and there is, therefore, a narrow range in which these types are competitive.

POWER REQUIREMENTS

The power required to drive any type of fan is a function of the volume of air handled and the pressure or vacuum obtained. The pressure is usually measured in ounces per square inch, but is often expressed in inches of water indicated by a water gauge, the measuring instrument commonly used, and which is located at the inlet or outlet of the fan.

The cubic foot is usually taken as the unit of volume or quantity and is expressed in terms of free air or gas, that is, cubic feet of air or gas at atmospheric pressure. The unit of time most generally used is the minute.

The relation between pressure in ounces per square inch and the reading of the water gauge in inches is shown by the formula:

$$WG = 1.728\ P, \text{ or } P = \frac{WG}{1.728}$$

Where,

$P =$ Pressure per square inch in ounces.
$WG =$ Pressure in inches water gauge.
$Q =$ Cubic feet per minute.
$K =$ A constant.

With constant volume the power is directly proportional to the pressure; with constant pressure the power is directly proportional to the volume handled per minute. The general equation is, therefore:

$$\text{Horse-power (theoretical)} = \frac{K \times Q \times WG.}{33\,000}$$

Centrifugal Fans—The above formula takes no account of the losses in the fan and therefore the actual brake horse-power required at the shaft of the fan will be greater in inverse proportion to the efficiency of the fan under consideration.

The formula then becomes:—

$$\text{Brake horse-power at shaft} = \frac{K \times Q \times WG}{33\,000 \times \text{Eff.}}$$

$K = 5.2$ for centrifugal fans.
Eff. = efficiency of the fan expressed as a decimal fraction,
= 0.40 for steel plate, 0.48 for Sirocco and 0.60 for cone type fans.

The following mathematical relations are theoretically true for all centrifugal fans and may be used in calculations:—Volume varies as the speed; pressure varies as the square of the speed; and horse-power varies as the cube of the speed.

Thus, if a fan delivering 8 000 cubic feet of gas at ½-ounce pressure when running at 100 r.p.m., requires two horse-power; the same fan at 200 r.p.m. will deliver 16 000 cubic feet at two ounce pressure and will require 16 horse-power provided the other conditions are not changed.

One marked characteristic of the centrifugal type of fan is that a reduction of the inlet or discharge area will reduce the power required if the speed remains constant, and if the area is increased the amount of power will be increased. This does not contradict the formula given, for although the pressure will be increased by a reduction of area, the volume will be reduced in a much greater proportion. With entirely closed outlet the power required is about 20 percent of that with an open outlet.

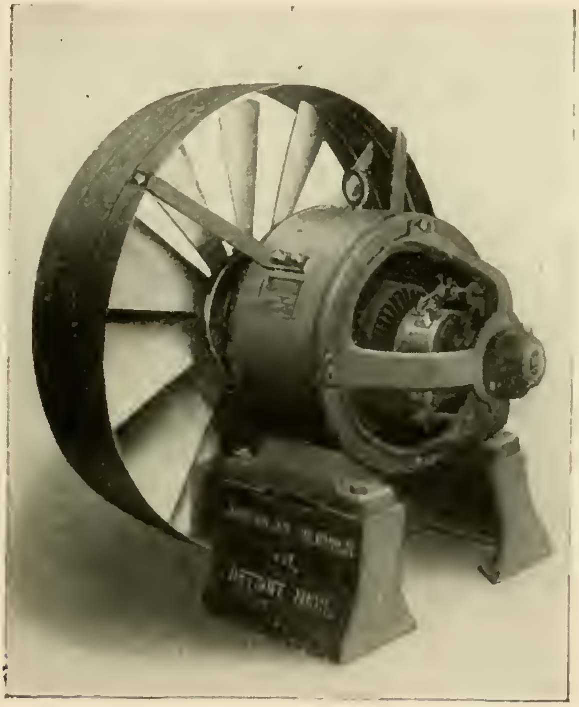


FIG. 5—DISC OR PROPELLER FAN

Disc Fans—The pressures are very low in the service covered by disc type fans and it is customary to figure on the basis of velocity rather than pressures. In this type, also, the above general relations between volume, pressure and horse-power are true. If, however, the outlet is restricted, the power and the pressure will both increase until, with an entirely closed discharge, about twice as much power is required as with an unrestricted outlet. It should be noted that the characteristics of the centrifugal and disc fans are entirely opposite in regard to power requirements with restricted openings.

Positive Pressure Blowers and Exhausters—The horse-power required for positive pressure blowers and exhausters may be approximately very closely by the following rule used by the manufacturers:—

Allow five horse-power for every 1 000 cubic feet per minute displaced against a pressure of 16 ounces per square inch; thus it will require 15 horse-power for a blower displacing 2 000 cubic feet per minute against 24 ounces pressure. The displacement per revolution multiplied by the revolutions per minute is the displacement per minute. Theoretically, the volume delivered will be equal to the displacement, but in practice there is always a certain amount of slippage which reduces the delivered volume. This slip depends on the gas handled, the speed, and the pressure. For the ordinary range of pressure for which this type is used the slip varies directly as the pressure and as the square root of the speed. The slip is also a function of the clearance, but while the actual clearance is larger in the larger sizes, the percentage of clearance to volume displaced is much smaller; therefore, the larger sizes have smaller percentage slip than the smaller ones. For handling air the volume delivered varies from 80 to 90 percent of the displacement, and for service as gas exhausters, only from 60 to 75 percent of the displacement is delivered.

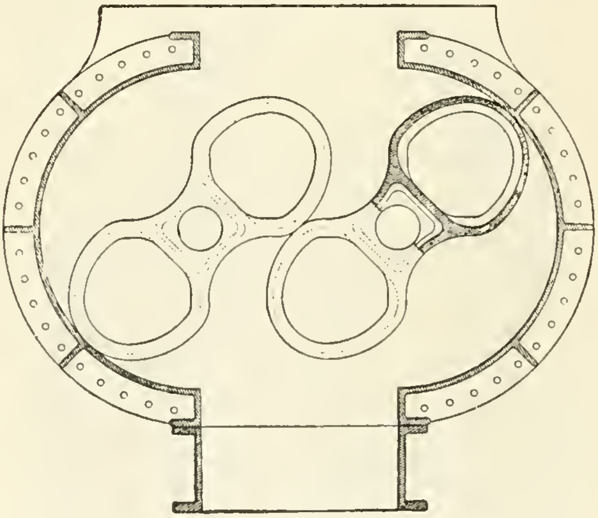


FIG. 6—CROSS-SECTION OF POSITIVE PRESSURE BLOWER

Since the volume discharged is approximately constant regardless of the pressure, any reduction of the inlet or outlet will greatly increase the power required. In this respect the positive pressure type is analogous to a plunger pump, while a centrifugal fan follows the laws of a centrifugal pump. The limiting pressure with restricted outlet is hard to predict but will be great enough either to burn out the motor, or to wreck the blower if the motor is large enough to maintain the load. The limiting condition with closed inlet is atmospheric pressure, but as this is several times greater than the usual pressure produced, the motor would probably burn out before wrecking the blower.

GENERAL

In making recommendations for motors to be used for driving blowers or exhausters it should be remembered that the nameplate, size or number gives no indication whatever of the amount of power required. The same fan will require many times as much power in some conditions of service as will be required under other conditions. If the volume and pressure are known, the application is a simple one, but for some purposes the only way in which the required volume and pressure can be satisfactorily determined is by trial. In the majority of cases the experience of the manufacturers will enable them to predict the requirements and conditions with sufficient accuracy.

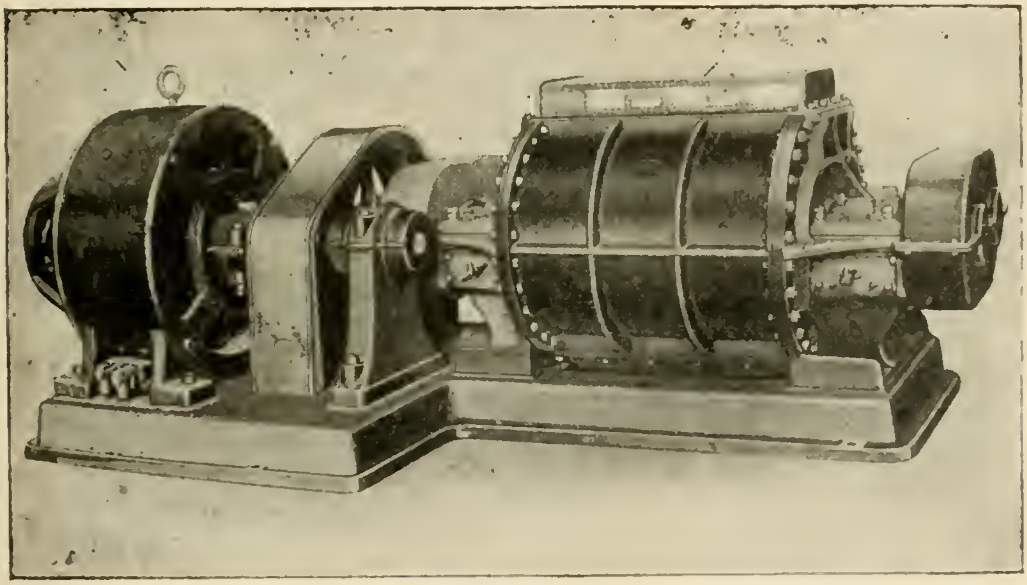


FIG. 7—POSITIVE PRESSURE BLOWER OR EXHAUSTER

MOTOR-DRIVEN ATTRITION MILLS

J. R. OLNHAUSEN

ATTRITION mills are used in the shelling of corn and grinding shelled corn, oats, cotton seed cakes, etc. They are also used extensively in flour, feed and cotton seed oil mills. There are man ydifferent types of these mills, all of which tend to produce the same result but differ from each other in detail of construction. An attrition mill consists primarily of two heads, rotating rapidly in opposite directions, on which are bolted the grinding plates. The shafts which carry the running heads are each supported by two bearings mounted on a bedplate. The product to be ground enters the mill through a hopper. At one end of the mill is a handwheel by means of which the plates can be adjusted so as to give the desired fineness of product. On this end there is also a quick release device, which permits the separation of the plates when any foreign matter enters the mill, thus preventing serious damage. It is essential that the plates be the same distance apart at all points so that the ground product may be of uniform fineness. When parallel in this manner the plates are said to be in tram. As the bearings become worn there is a tendency on the part of the plates to get out of tram, and tramming devices are usually supplied which may be used in aligning worn bearings so that the plates can again be put in tram.

When the question of applying motors to these mills was first taken up it was decided that the best arrangement to use would be an engine-type motor, mounting the stator on the base and the rotor on the shaft of the mill. Upon investigation, however, it was discovered that the tramming devise would not allow this, as every time the bearings were adjusted, the position of the rotor would change relative to the stator, thus changing the air-gap. In some instances it was found that the rotor would rub on the stator. For this reason the application of direct-connected motors to these mills was abandoned for some time.

The Munson Brothers Company of Utica, N. Y., again took up the matter of applying direct-connected motors to their mills and conceived the idea of mounting the stator on a cradle which was fastened to the bearings. In this way the shifting of the bearings would not change the position of the stator with respect to the rotor, inasmuch as both were moved the same distance. This Company still uses this plan and quite a number of these motor-driven mills are in successful operation.

It remained, however, for the Sprout-Waldron Company of

Muncy, Pa., to develop a mill that required no tramming device. This was accomplished by the use of ball bearings, which they found—after long experiment—showed practically no wearing and that, if the plates were originally built in tram, they would remain in that position. This necessitated very accurate machining of the pedestals and bearings. They then took up the matter of applying direct-connected motors to their mills and it was found that the stator could be placed on the base of the mill if the base of the stator was machined so that the distance from the base to the center line of the shaft would be as accurate as was needed to give an equal air-gap at all points. It was also found necessary to have the width of iron in the rotor greater than that used in the stator so that when the plates were adjusted, or separated, the stator iron would not overlap the rotor iron, thus causing magnetic pull. The original idea of furnishing engine type motors was carried out.

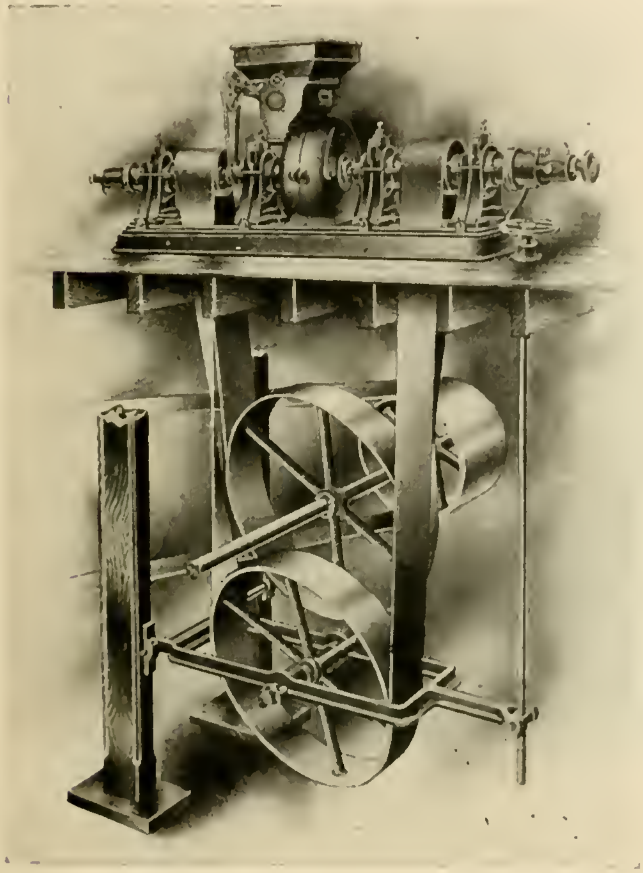


FIG. 1—BELT DRIVEN ATTRITION MILL

The squirrel cage induction motor is used exclusively with these mills. The size of the mill is expressed in inches, referring to the diameter of the grinding plates. The sizes most commonly found in flour mills, with size and speed of motors are as follows:

Size of Mill	20	24	30
Hp of Motor	10	15 & 20	25 & 30
Speed, r.p.m	1740	1740	1710

In the grinding of cotton seed cakes the 32 inch and 36 inch mills are used, the former requiring 25 to 40 horse-power, 1710 r.p.m. motors, and the latter 40 to 50 horse-power, 1140 r.p.m.

motors. One standard auto-starter with no-voltage and over-voltage release attachments is used for starting both motors.

The main advantage of the motor-driven mill over the old belt driven machines can be readily seen from the comparative illustrations, Figs. 1 and 2. In order to drive the two grinding plates in opposite directions from belts it is customary to provide pulleys which are equal in diameter to the distance between the driving pulleys on the mill shafts. This requires considerable space, either overhead or beneath the floor, as well as devices to maintain the belts taut. The heavy pull necessitates large bearings, which require valuable space. The advantages of the motor-driven type are:—

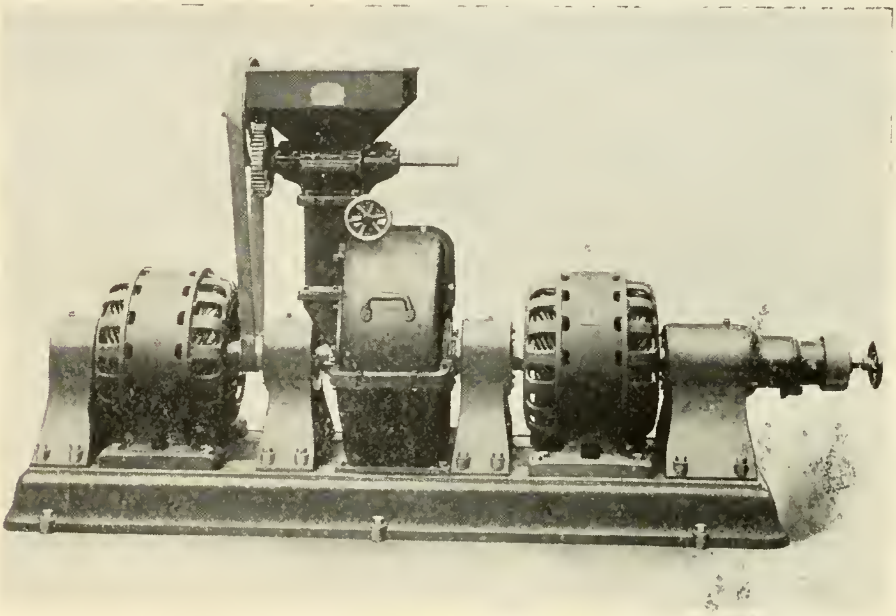


FIG. 2—ATTRITION MILL DRIVEN BY TWO INDUCTION MOTORS

1—Eliminating of all belts, shafting, pulleys, which reduces the cost of maintenance, and also reduces friction losses to a minimum.

2—Saving in floor space: a motor-driven mill can be placed in any part of the building, which is not the case with belt driven mills.

3—Greater uniformity in speed, since slip of motors with changes of load will be considerably less than belt slip. This gives increased production and better quality of ground product.

4—Ease of reversing; with a motor driven mill this is accomplished by throwing over a double-throw knife switch, while with the belt driven mill, the shifting of belts on tight and loose pulleys is involved.

5—Power is applied at the point where the work is to be done.

THE SMALL MOTOR IN THE HOME

JAMES C. MUNN

ALMOST every one living within reach of central station circuits is now familiar with motor-operated vacuum cleaners, washing machines, ice cream freezers, polishing lathes, grinding lathes and sewing machines. Many homes have one or more of these motor-operated machines in service, but commonly each device is equipped with its own motor and the cost of a complete outfit, each with an individual motor, amounts to several hundred dollars. Motors of a general utility nature have been on the market for some time, but many of these are too small to do more than light polishing, grinding and ventilating, and few if any are large enough to be applicable to washing machines and vacuum cleaners. The object of this article is to show, by citing a few examples, how one stock motor can be made to do the difficult parts of a number of household tasks, and thus bring down the cost of a household outfit to a point where any family using electric lights can afford to have a number of motor-operated devices. The outfits here described are all in regular use within a restricted area near the writer's home. In each case the motor application has been made by the owner without any expert assistance.

A motor for household use should be selected with regard to the apparatus it is to drive, and here the dealer's advice should be sought. Motors of one-quarter horse-power and less can usually be connected to any lamp socket and started by an ordinary snap switch; for large motors special wiring and switches, and for sizes larger than one-half horse-power, starting boxes may be necessary. Motors larger than one-quarter horse-power are rather heavy to handle and are not to be recommended for portable outfits. Usually there is no difficulty in installing special wiring for a non-portable motor, as ordinarily it is located in the basement.

The non-portable motor may require a shaft to transmit the power to the point of application, but where more than one-quarter horse-power is needed, this method has many advantages. The portable motor outfit is usually less expensive, but the motor is necessarily smaller and less powerful. It can, however, usually be arranged to drive a larger number of devices than can the non-portable motor. For the usual family size washing machine, a one-sixth horse-power motor is sufficient; a four-quart ice cream freezer requires at least that much power, especially after the cream begins to freeze; one-eighth horse-power is sufficient for a two-quart freezer, a small portable vacuum cleaner, or a small washing machine. A small stationary vacuum cleaner requires a one-quarter horse-power motor, while a medium sized one requires one-half horse-power or more. The motor should be selected for the device requiring the most power, and will then of course be ample for the other devices.

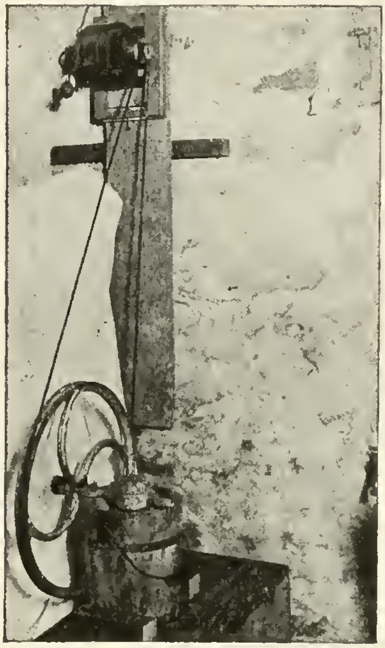


FIG. 1—ICE CREAM FREEZER BELTED TO WALL-MOUNTED MOTOR

OUTFITS WITH NON-PORTABLE MOTOR

Outfit A represents a very simple form of non-portable motor installation. A one-eighth horse-power motor is mounted on the basement wall and can be belted to a small lathe, an ice cream freezer, or a clothes washing machine. The motor is bolted to a wooden block with flanges on each side, which can slide up and down in a wooden frame permanently fastened on the wall. The belt tension is adjusted by a screw on the frame by which the motor is raised or lowered. Fig. 1 shows the motor belted to an ice cream freezer which was originally operated by hand; the crank has been replaced by an old iron wheel having a groove for round belting. The same motor is shown belted to run a washing machine in Fig. 2. The washing machine also was originally hand operated. The belt wheel used with the ice cream freezer is made use of here also. For running a small lathe the grooved pulley is replaced by a flat one as shown in Fig. 3. Any kind of wood turning, and light metal-turning can be done on this lathe as well as grinding and

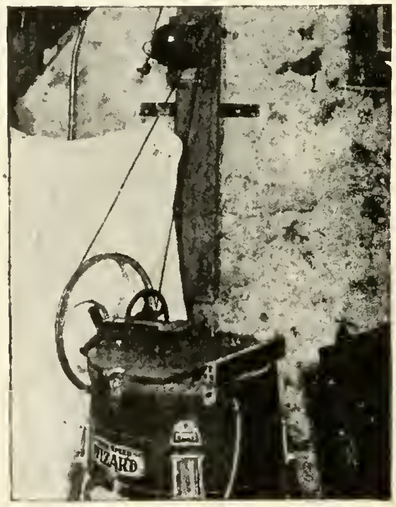


FIG. 2—WASHING MACHINE BELTED TO SAME MOTOR

The belt wheel used on the freezer is transferred to the washing machine which can also be operated by the motor.

polishing. A circular saw can be arranged as shown in Fig. 4. Here the motor is fastened to the bench top by thumb screws and a box for guiding the lumber is placed over the saw.

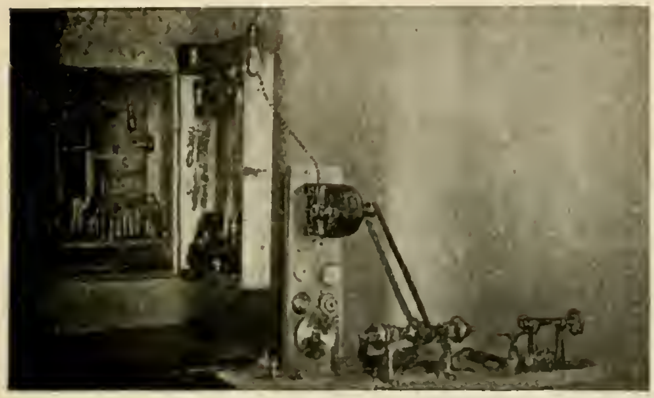


FIG. 3—A SMALL LATHE
The motor can be belted to a small lathe for wood and light metal turning and also for grinding, polishing, etc.

Outfit B—A number of different and important services are performed by the one-half horse-power motor shown in Fig. 5, and the outfit illustrates to what good advantage a non-portable motor can be put by the use of a little ingenuity. The outfit includes a stationary vacuum cleaner, a clothes washing machine, a dish washing machine, an ice cream freezer and a small lathe for grinding and buffing wheels. The vacuum cleaner pump, dust tank and motor are mounted on a specially made table in the cellar, the pump being driven by a flat belt. The two suction pipes shown at the extreme right in Fig. 5 extend upward through the walls at about the middle of the house. Pipe openings for hose attachments are located beneath the baseboards in a couple of rooms on each floor, and are so distributed that a 20-foot hose can give service to any part of the ten rooms. The dust tank opens downward so that the cleaner can be emptied with but little work, the dust being burned in the furnace. The usual variety of cleaning tools are available for cleaning carpets, tufted furniture, portiers, mattresses, walls, corners, etc.

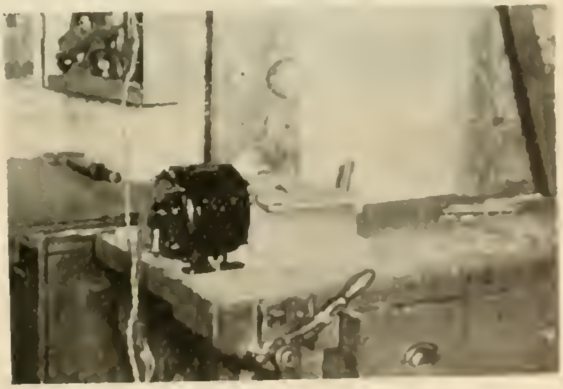


FIG. 4—OPERATING A CIRCULAR SAW
Another one of the motor's duties

The motor shaft is long enough to carry a second pulley, which turns a short line-shaft extending into the laundry under the kitchen. The dish washing machine, which is installed in the kitchen, was made by the owner. It consists of a receptacle for the dishes which sets in a larger cylindrical container for the water, and is driven at about 200 r. p. m. by means of a vertical shaft and a mitre wheel driven by a belt which runs through openings in the kitchen floor to the line shaft below. The dish container has flanged openings in the bottom, and when it is rotated in the proper direction, soapy water is forced to circulate rapidly upward through the stack of dishes. After the dishes are cleaned, which takes only a couple of minutes, the soapy water is drained and clean hot water is run in to rinse them. After this water is drained, another minute's running throws off all the water from the dishes by centrifugal force so that no other drying is necessary. A large pile of dishes can be washed and dried in this machine in ten minutes with no more work than is required to put the dishes in the machine and take them out again.

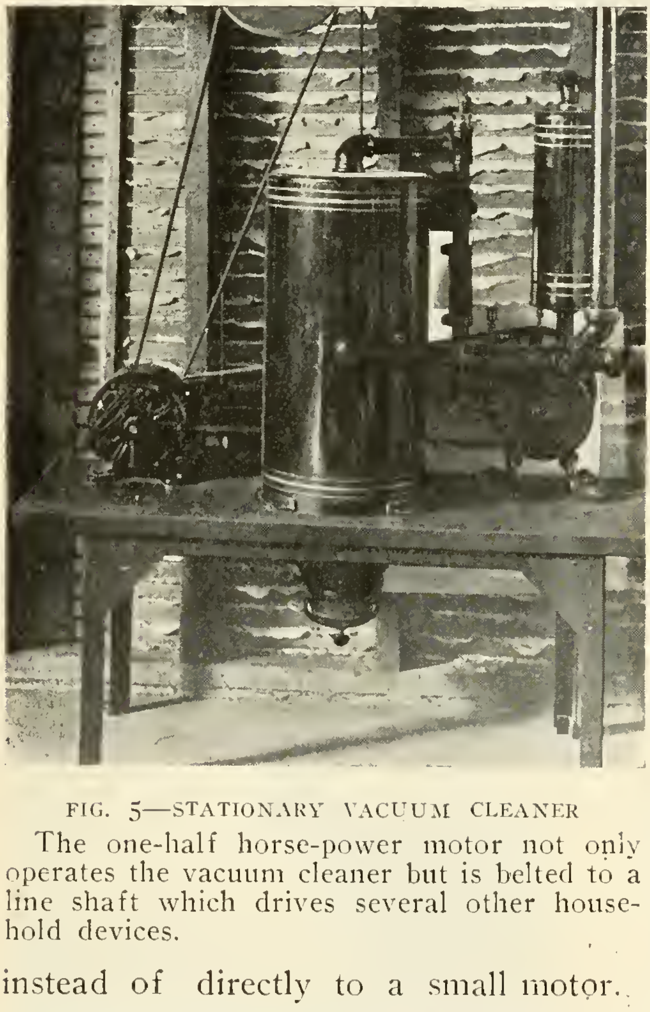


FIG. 5—STATIONARY VACUUM CLEANER

The one-half horse-power motor not only operates the vacuum cleaner but is belted to a line shaft which drives several other household devices.

The clothes washing machine, the grinding and polishing lathe, and the ice cream freezer are included in this outfit. They are somewhat similar to those described later in connection with other devices except that they are belted to the line shaft instead of directly to a small motor. The exhaust pipe of the vacuum cleaner is carried through a partition into the furnace room and can be arranged when desired to create a forced draft for the furnace. The motor is powerful enough to operate several of the devices at the same time, and can be started by switches in the cellar, the kitchen, or the second floor.

Outfit C—A very simple arrangement is indicated in Fig. 6, where the motor is permanently attached to the under side of the table of an old sewing machine. The motor brackets were, of course, revolved 180 degrees so as to bring the oil cups below the bearings. The motor pulley extends beyond the edge of the table so that a belt can be run from the pulley to a lathe head mounted on the top. This lathe was made by the owner out of pipe fittings, which are lined with babbitt metal for the bearings. Chucks for holding grinding and polishing wheels, drills and circular saws can be used in connection with the lathe, or they can be attached to a flexible shaft and thus may be used at any angle and at any distance within the length of the shaft. The motor pulley has a large and a small step, the smaller being used for belting to a washing machine or ice cream freezer. The ice cream freezer was originally operated by hand but has been arranged for driving by motor without removing the handle, so that if necessary it can be turned by hand without any changes or adjustments whatever. A heavy box serves to support a counter-shaft, which carries a home-made wooden wheel grooved for a belt; a hole near the edge receives the freezer handle. The freezer pail is held by clamps to a platform in such a way that the freezer shaft is in line with the counter-shaft as shown in Fig. 6.

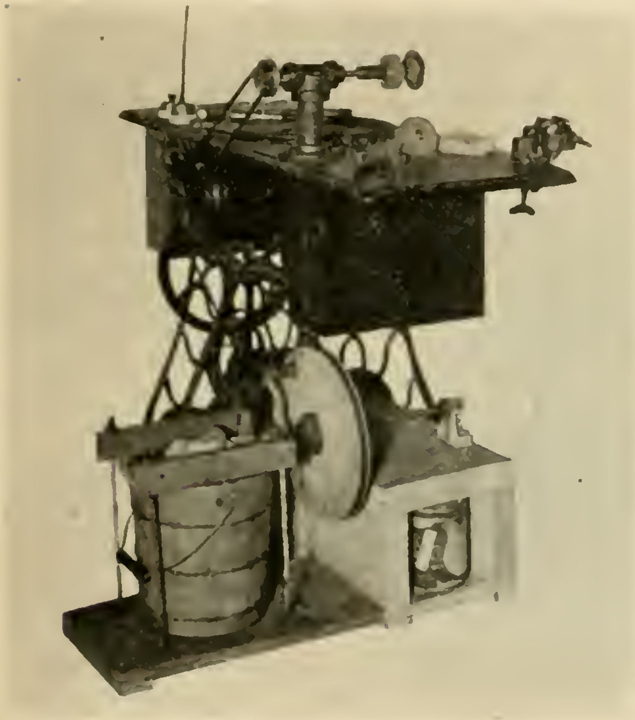


FIG. 6—A HOME-MADE POWER TABLE

The motor is out of the way under the top of the old sewing machine frame. The machine top is used for a workbench.

OUTFITS WITH PORTABLE MOTOR

Outfit D includes a vacuum cleaner, clothes washing machine and an ice cream freezer which were originally hand operated, and also a polishing wheel, a ventilating fan and a sewing machine. The motor which is rated at one-sixth horse-power is clamped to a small wooden base about one and one-half inches thick, which has a number of one-quarter inch holes through it. Iron dowel pins, projecting from the base of each of the driven machines, fit tightly into the holes in the motor base and keep the motor in position when it is belted. When used for polishing or with a ventilating fan, the wooden base serves only as a support for the motor. The vacuum cleaner pump was originally hand operated by means of a belt from a crank wheel which was mounted on a pedestal and at convenient height for the operator. One person was required to turn the wheel and another to handle the cleaning tool. The pump and the dust receptacle are mounted on a small platform on rollers. The only modification necessary to change to motor drive was to remove the pedestal and crank wheel, and place dowel pins in the platform for holding the motor in the proper position for belting, as shown in Fig. 8. With this arrangement there is no necessity for a second person to turn the crank wheel, and the vacuum cleaner is much more effective.

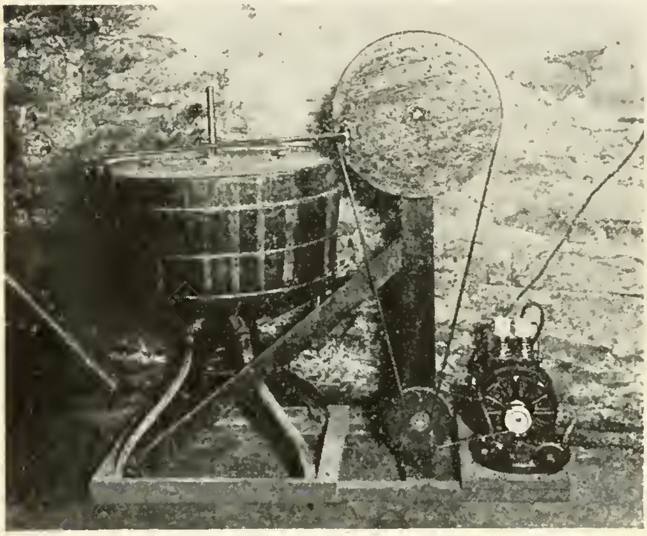


FIG. 7—A REVERSING TUB DOLLY-TYPE WASHER
This washer was originally hand operated. Now the motor does all the hard part of the work.

The washing machine is of the reversing-tub dolly type, and is operated with an oscillating motion. It was originally run by hand but has been adapted for motor drive as shiwn in Fig. 7. The motor and washing machine are on a common base to which the motor is attached by the dowel pins. The original operating arm of the washing machine is attached by a swivel joint to the edge of a homemade wooden wheel which is driven by a belt from a speed-reducing pulley below it.

For application to the ice cream freezer, the motor and freezer are attached to the same platform, as in the previous cases; the crank has been removed and replaced by a homemade wooden wheel grooved for the belt.

By means of a set screw, a chuck for holding a polishing or grinding wheel can be attached to the extended motor shaft.

The polishing wheel is used for polishing silverware, and the emery wheel for keeping knives, choppers, etc., sharp, and also for any kind of light grinding required in the home. A fan can also be attached in the same manner as the chuck. This is used to circulate the air in the summer, and in the winter to distribute heat from the furnace throughout a room.

For operating the sewing machine, the motor is placed on the machine top just back of the hand wheel so that the motor pulley lines up with the belt groove on the hand wheel. The rod connecting the treadle to the large wheel was removed and the belt passed around the treadle wheel, the hand wheel, the motor pulley and an idler pulley, which is on a lever arm attached to the motor. This lever arm is shown on the motor in Figs. 7 and 8, and is permanently attached, as it is not in the way when the motor is being used for other purposes. A chain from the lever was attached to the tip of the treadle and by this means the speed of the sewing machine is controlled. The motor is in continuous operation while the machine is being used. By pressure on the treadle, the idler pulley tightens the belt and also lifts a brake-shoe from the rim of the hand wheel, thus starting the machine. If there is no pressure on the treadle the belt is loose while a spring holds the brake-shoe against the hand wheel, preventing it from turning.

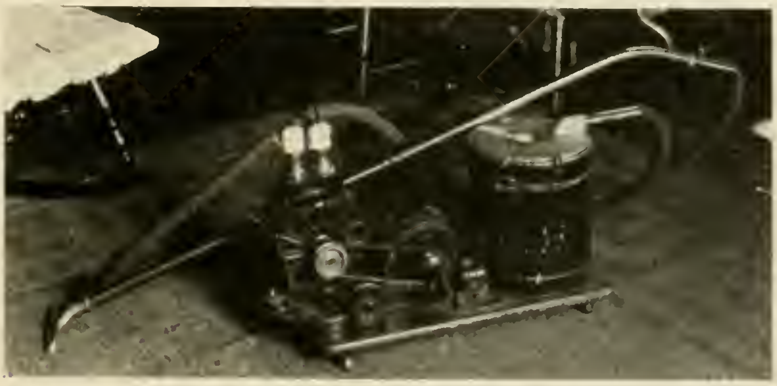


FIG. 8—PORTABLE VACUUM CLEANER

This vacuum cleaner used to be operated by hand and required two persons; one to turn a crank, another to handle the cleaning tool. With the motor, one person can do all the cleaning with very little labor.

Outfit E is equipped with a one-sixth horse-power motor. The principal application is to a vacuum cleaner which the owner, being of a mechanical turn of mind, made himself, the cost of material being less than $15. The dust receptacle, motor and fan are mounted on a rolling platform. A photograph of the vacuum cleaner is shown in Fig. 9, and a sectional sketch in Fig. 10. There is a cylindrical tank, *a,* a volute fan *b,* which draws through a dust bag *c,* and discharges radially through the outlet *d.* The partition and ends are of wood, fitted so as to be air tight. The motor, which runs at 1 120 r.p.m., operates the fan at 3 000 r.p.m. by a rawhide gear. The dust bag is held by a wire ring *e* which fits into an annular groove in the wood seat *f.* The head *g* is held in position by carriage bolts *h* and wing nuts, and the felt washer *i,* makes the joint air tight. The owner claims that the horizontal position of the tank and bag is very desirable because the top of the bag is always dust free and the suction therefore is more uniform than if the air has to be drawn through whatever dust is in the bag, as is sometimes the case with vertical tanks. The motor is attached to the vacuum cleaner platform by bolts and wing nuts so that it can be easily removed for other uses. The cleaner is used only about two hours one day each week to go over a nine room house.

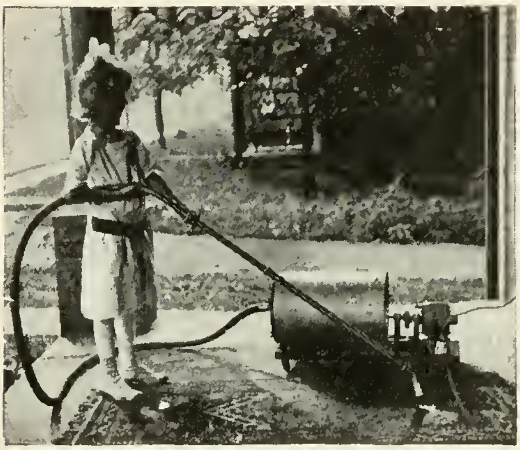


FIG. 9—HOME-MADE VACUUM CLEANER

With a little mechanical ability and inexpensive materials this device for making the housekeeper's work easier was built by the owner.

Besides operating the vacuum cleaner the motor can be fastened to a bench and belted to a small lathe; a flat belt is used, the rawhide pinion acting very satisfactorily as a pulley. The lathe has a variety of chucks for drilling, grinding and polishing, also a flexible shaft to which the chucks can be attached.

Outfit F—The little one-twelfth horse-power motor of this outfit operates a clothes washing machine, an ironing machine, a sewing machine, a vacuum cleaner, a ventilating fan, a grinding wheel or a buffing wheel. The motor weighs but little more than an ordinary flat iron and can be easily transferred from one device to another. On the motor frame is a plug switch for attaching a conductor cord through which current is brought from the nearest lamp socket, and also a small home-made knife-switch for reversing the direction of rotation. Practically all the devices used in applying the motor are home-made from materials which were obtained at small expense. The motor is held in place in nearly the same manner as the motor of outfit *D,* except that no wooden base with holes in it is used; instead, each side of the cast iron foot of the motor has a deep notch into which dowel pins, projecting from the mounting for the motor, fit tightly enough to hold the motor rigid; and also serve to keep the motor in proper alignment. The motor can also be slightly shifted to obtain proper belt tension, by adjusting the pegs which fit into the holes in the motor base.

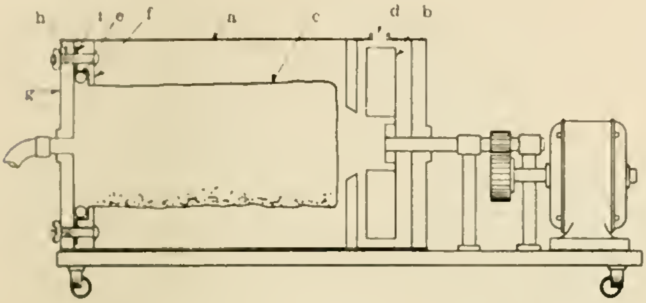


FIG. 10—CROSS SECTION OF VACUUM CLEANER SHOWN IN FIG. 9

This machine cost little as compared with commercial vacuum cleaners and the motor can be easily removed for other purposes.

The washing machine is of the rub-board type and has an iron wheel about 16 inches in diameter which, through reduction gears, gives a rocking motion to the cradle. To adapt for motor drive, the handle was removed and a groove turned in the rim of the wheel for a belt; the motor is placed on the lid of the machine with the pulley in line with the wheel. In order to hold the motor on the machine lid when the washing machine is opened, metal strips are clamped over the projections of the motor foot, as shown in Fig. 11.

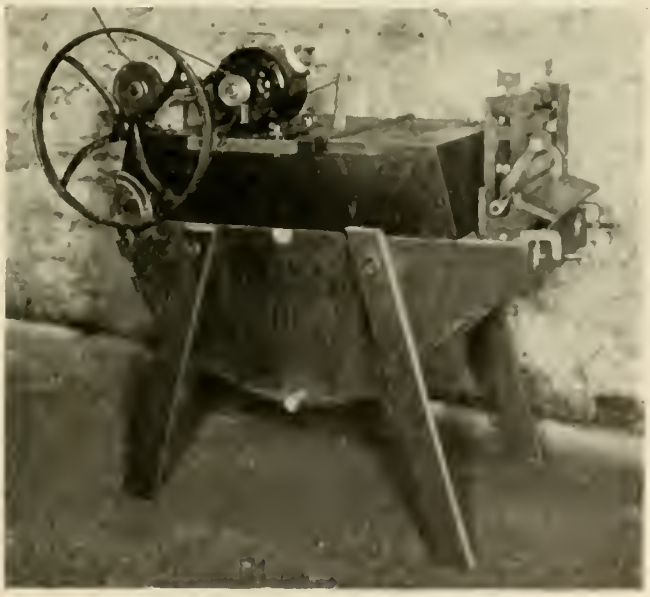


FIG. 11—SMALL MOTOR APPLIED TO RUB-BOARD TYPE WASHING MACHINE

This washer was easily adapted for motor drive.

A 31-inch home laundry mangle, built as a hand operated machine, required a speed reducing gear in addition to the several originally on it, in order to drive it by the motor. The crank was replaced by a wheel taken from a vacuum cleaner similar to the one described in outfit *D.* The motor speed, 1700 r. p. m., was reduced through the gears so as to give the roll an ironing speed of ten feet per minute. The great advantage of motor drive is, of course, that the ironer can be operated by one person instead of two, and the motor gives a constant speed, which results in smoother work. The rolls, which are heated by gas, are mounted on a homemade table, and the motor is mounted on a platform below the table top as shown in Fig. 12. A sewing machine treadle has been arranged so that the pressure of the roll can be released or applied by the operator's foot. A switch is placed under the table top convenient to the operator, for stopping the motor whenever an immediate stop is desired. The table frame is of gas pipe, mounted on rollers, which make the table easy to move about. A drying rack of three-eighths inch pipe has been provided for disposing of the pieces as they are ironed. The rack is over the iron, the heat of which helps dry the goods, and the position of the iron is such that all the extra heat goes up and none of it comes out toward the operator. This machine handles all classes of flat work, and also underwear, hosiery, etc. Ninety-five per cent of the usual ironing is handled by the mangle, and an amount of work that would require four hours to do by hand, can be done with this machine in one hour and with much less effort.

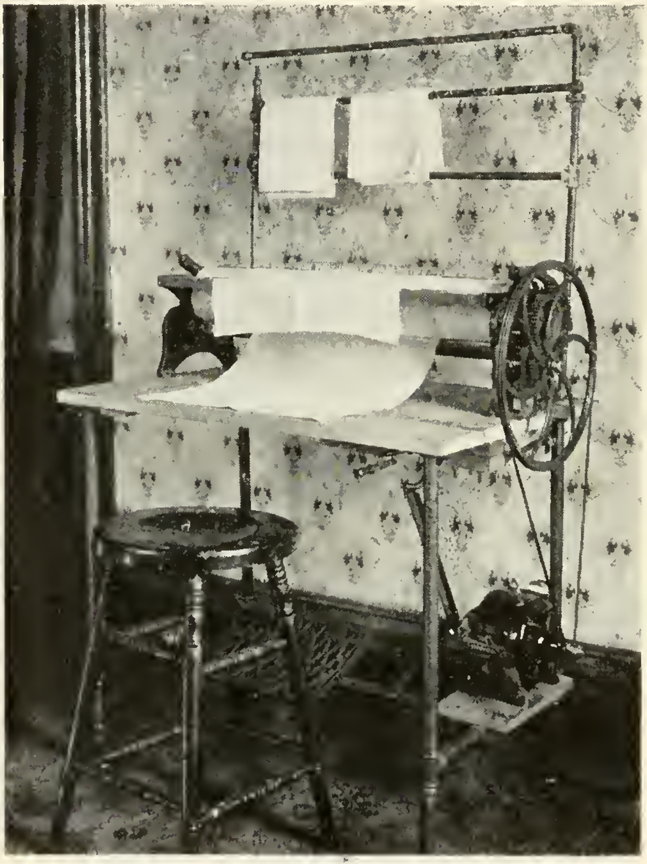


FIG. 12—HOME LAUNDRY MANGLE

This machine originally required two persons to operate it; with the motor only one person is required. Ninety-five percent of the usual family ironing is done on the machine, which does its work about four times as fast as can be done by hand.

In Fig. 13, the idler pulley, lever and brake necessary to control the speed of a motor-operated sewing machine are shown attached directly to the sewing machine top instead of the motor, as is usually the case. This is an original idea of the owner and advantageous in that the idler pulley is always properly aligned with the handwheel pulley, the pulley and the lever are not on the motor when it is being used for other purposes, and the motor can be applied to the sewing machine in a minimum time. In case the machine is not to be used for some time the idler pulley and lever are taken off. This is done by removing two thumb screws which hold the pulley base to a brass plate set in the table top. The operation and control of the sewing machine equipped with the motor is the same as described in outfit *D*. Fifteen minutes' practice gives the operator complete control and confidence, and sewing can be done in about one-third the time required by treadling. In all cases where a motor has been applied to a sewing machine the result has been that, because the laborious part of the work was eliminated, much sewing was done on it that was formerly sent out or a seamstress called in to do. In some cases old style hard running sewing machines, which ordinarily would have been discarded, were retained and were quite satisfactory with motor drive.

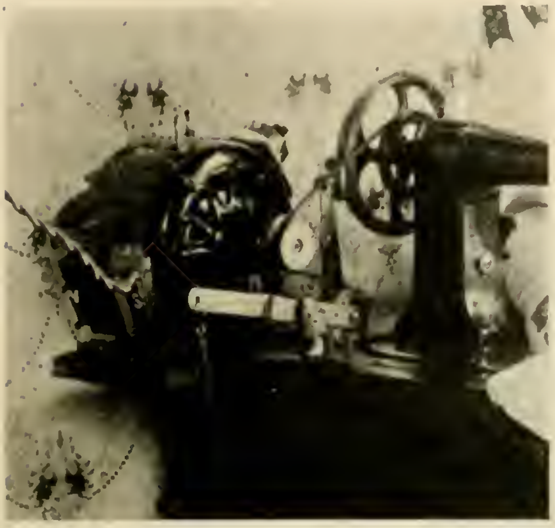


FIG. 13—THE MOTOR MAKES SEWING EASY
There is no treadling; the machine is easy to control, and the production is much greater.

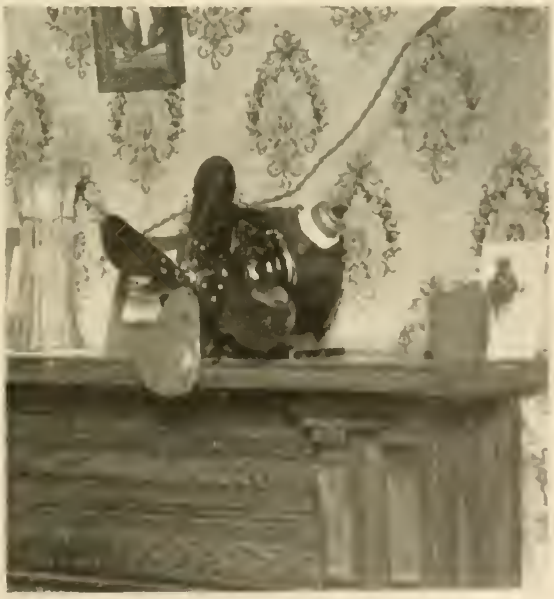


FIG. 14—ELECTRIC FAN
The motor shown in Figs. 11, 12, 13 and 15 is shown here operating a fan. The set of blades is attached by a set screw.

The vacuum cleaner is of the same make as the one described in outfit *D* and the application is very similar. The pedestal and crank-wheel of the cleaner used for hand operation were removed and the motor attached and belted to the pump with the result that the cleaner is much more affective than it originally was. Motor drive is much easier on the vacuum cleaner than hand drive because there is less vibration and strain. Another point in favor of motor drive is that there is less belting to keep up.

This motor can be converted into an electric fan by attaching a set of blades, as shown in Fig. 14. These are not expensive nor difficult to apply.. The bushing should have a set screw for attaching the fan to the motor shaft extension, and, if desired, a wire guard can be added.

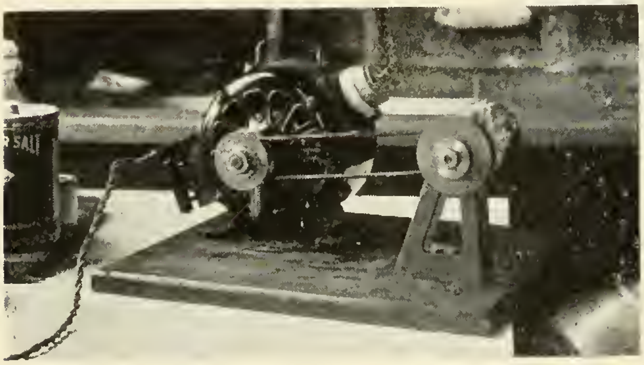


FIG. 15—GRINDING AND POLISHING OUTFIT
A very desirable adjunct to any home.

Fig. 15 shows the motor belted to a small home-made grinding and polishing outfit. This device is bolted on a 10 by 18 inch board on which a mounting for the motor is provided. A carborundum wheel is shown on one end of the shaft and a polishing wheel on the other. The pedestal was made from a piece of scrap brass. Effective grinding can be done with this apparatus and it is in continual use for sharpening knives and for polishing kitchen utensils and silverware.

THE MODERN MINE LOCOMOTIVE

H. K. HARDCASTLE

THE rapid increase in the use of electric locomotives for mine haulage in recent years, and the exceptionally severe operating conditions to which this type of locomotive is subjected, together with the ever increasing space limitations as the deposits become more inaccessible, have resulted in a demand for locomotives radically different from the older types. The more recent locomotives built for mine service are of exceptionally rugged characteristics, the wearing parts are accessible for adjustment or replacement, and all parts will operate under severe conditions of track, dirt, moisture and overloads without injury.

The inherent characteristics of the commutating pole motor, as developed for railway service, with its sparkless commutation at all loads, are well known. All of these characteristics are maintained in the newer types of commutating pole mine motors, and in addition certain mechanical features have been added which make them especially adapted to mine service. The motors are so mounted that all inspection, oiling and replacements can be made from above and without displacing the wheels, motor suspension or other parts. The motor frame is split diagonally as shown in Fig. 1. The axle caps and suspension lug are on the lower part so that the upper part, either with or without the armature and bearing housings, may be lifted off from above as shown in Fig. 2. At the same time the axle caps and suspension are so arranged that a set of wheels may be dropped out from below without displacing the motor or any of the wiring connections. In all but the largest motors two brush-holders are placed in the upper half of the motor frame under a large commutator opening, and the brushes may easily be inspected or renewed by one man, and without any tools.

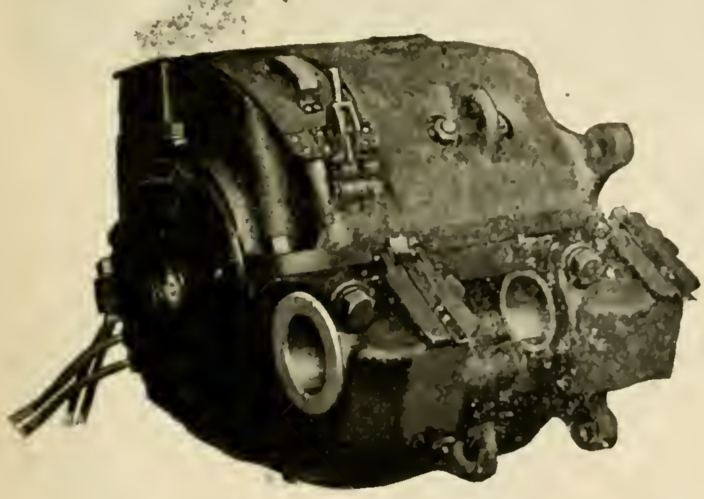


FIG. 1—SPLIT FRAME MINE MOTOR

From the same position lubrication may be supplied to all moving parts, as shown in Fig. 3.

The cast steel bar type of locomotive frame has long been standard in steam locomotive construction on account of its ruggedness, its ability to resist shocks and the great strength per unit of weight. In addition to these advantages it is especially adapted for use in a mine locomotive on account of the complete accessibility afforded to all interior parts. With this construction all bearings, grid resistance, brake rigging, etc., may not only be reached from the side of the locomotive, but they are at all times visible to anyone passing, and any slight trouble can be seen and rectified at once before be-

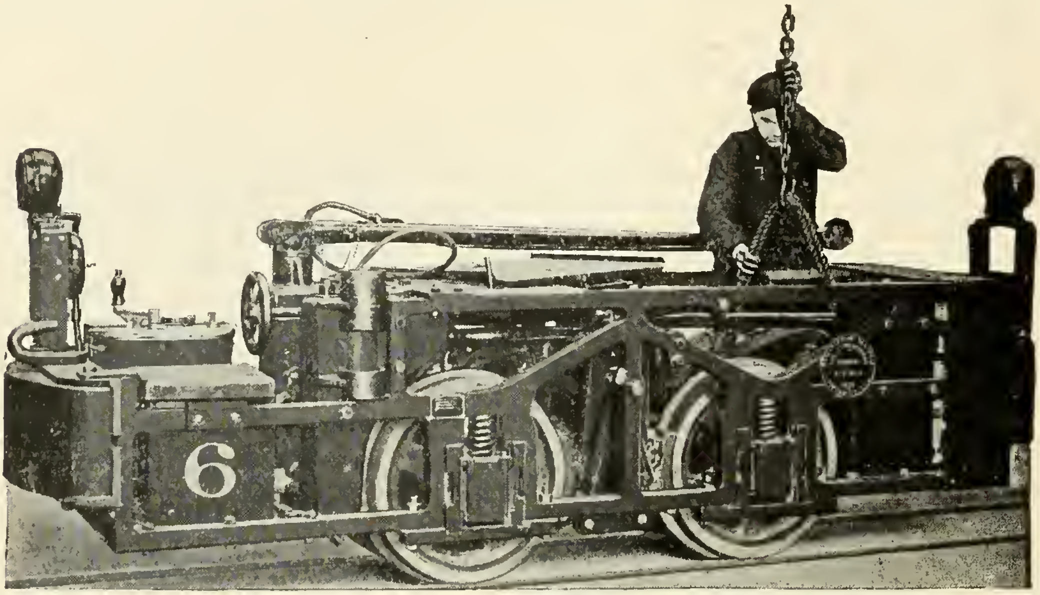


FIG. 2—METHOD OF REMOVING ARMATURE

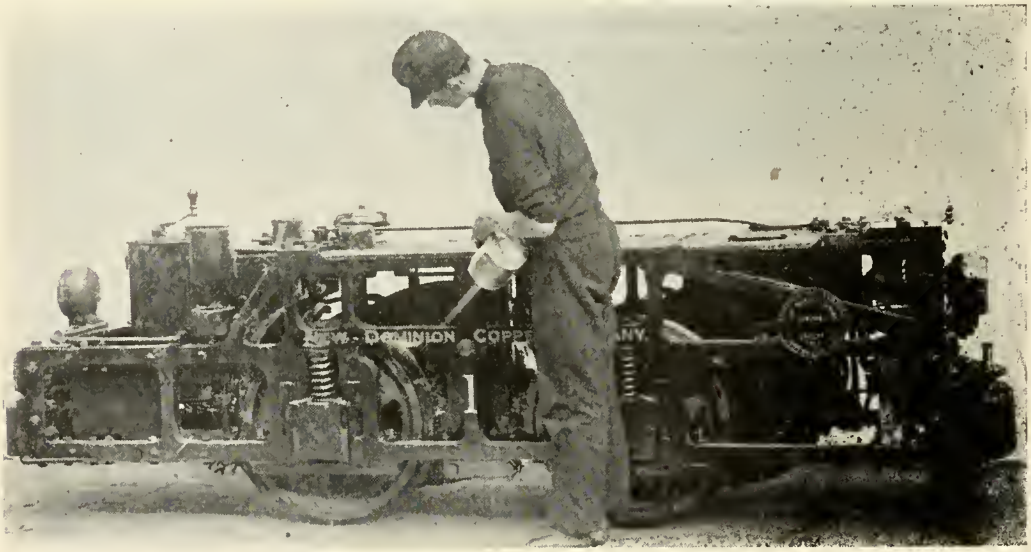


FIG. 3—ACCESSIBILITY FOR LUBRICATION

coming serious. Another very considerable advantage of the bar type frame construction is the free circulation of air permitted, and the complete ventilation of the motors and grid resistance. The cooling effect of this free circulation of air is such that the capacity of the equipment is perceptibly increased over that possible where the enclosed type of construction is used.

By the use of the cast steel bar construction in the locomotive frames it was found possible to design a composite type of frame which would be suited to locomotives having different wheel bases. By this means the same frame may be used both for inside and for tandem hung motors, as well as for frames inside or outside of the wheels. This point is of considerable importance both to the manufacturer and to the operator since by reducing the number of different standard parts required, it becomes feasible to keep the remaining parts in stock and thus quick deliveries are made possible.

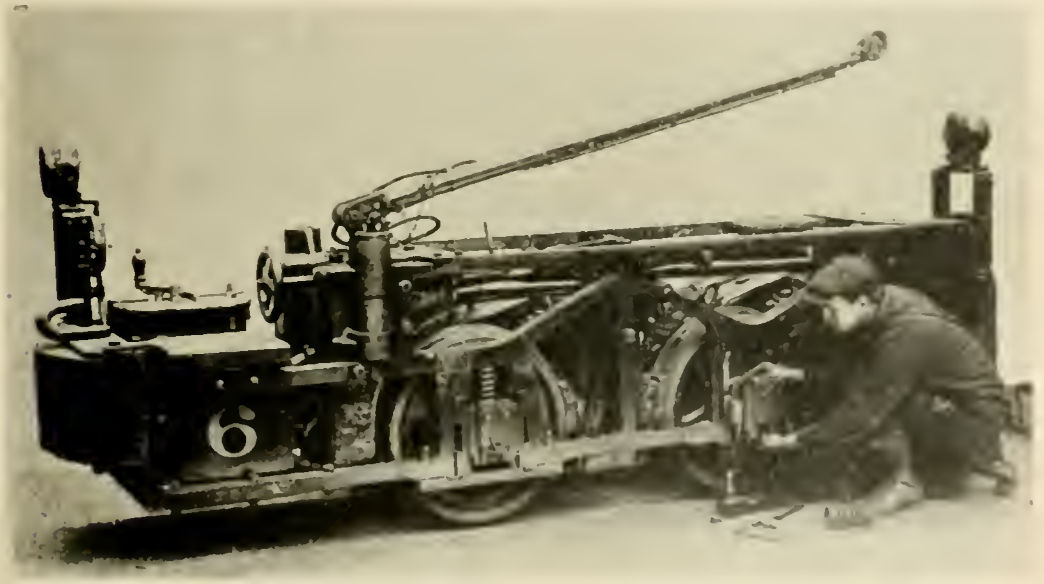


FIG. 4—REMOVING JOURNAL BOX

In connection with the development of the cast steel bar type of frame every effort was made to arrange all wearing parts so that they might be inspected or removed with a minimum cost of time and labor. With this end in view a patented removable gib is supplied between the journal box and pedestal jaws on locomotives built with outside frames. With this type of gib it is only necessary to take the weight off the journal and drop the binder, when the entire journal box may be slipped out sideways as shown in Fig. 4. On locomotives built with inside frames the oil cellars are arranged to be easily dropped out for repacking or inspection. If it is desired to take the box out entirely it is only necessary to remove the binders and jack up the locomotive sufficiently so that the box will clear the pedestal jaws, when the box may be rotated about the axle and will then drop out.

Owing to the steep grades present in many mines the brake rigging is a matter of great importance and to meet these severe conditions a very simple and powerful form of brake has been developed. This brake is of the automatically locking screw type which may be quickly applied and adjusted to the braking power required. It is at all times capable of slipping the wheels. The brake rigging was designed to require the minimum attention in service, the only adjustment necessary being that to take up slack as the brake shoes become worn. The brake shoes, as will be noted in Fig. 5, are arranged to be replaced as on standard car equipments, and this, as well as adjustment for taking up slack, can easily be accomplished from the side of the locomotive.

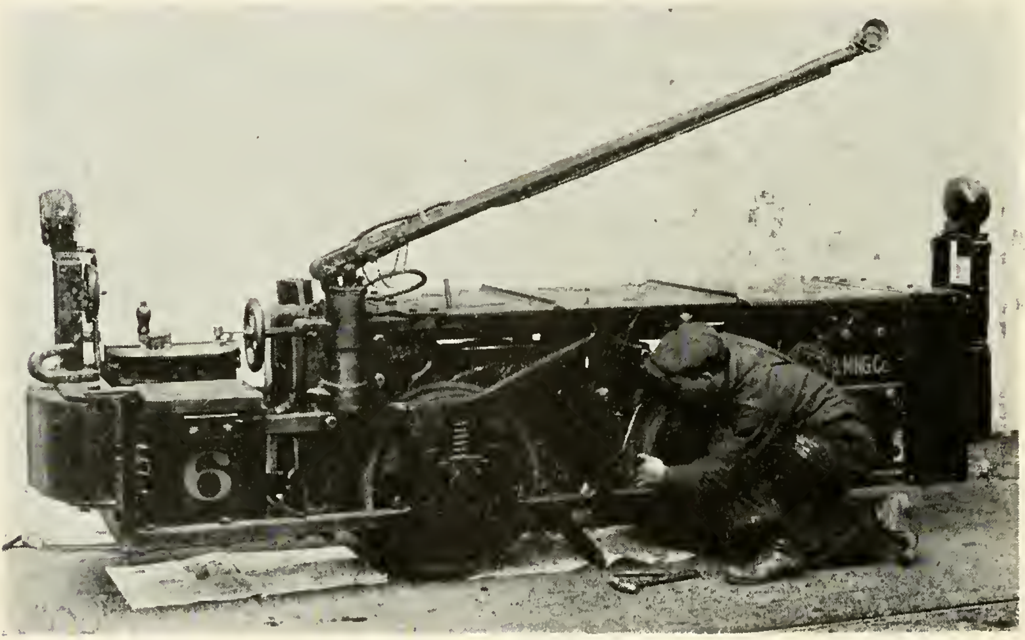


FIG. 5—REPLACING BRAKE SHOES

In many mines the conditions are such that the position and height of the trolley wire are constantly changing. A new design of trolley has been brought out to meet the demand for a type that could be mounted at a convenient place on the locomotive, and which from this point would be adapted to the trolley wire as located above either side or the center of the track, and which would give an approximately constant pressure on the wire through a wide range in height. Other conditions considered were to produce a trolley that could be reversed in a narrow passage by the motorman without leaving his seat, and at the same time one which, though adapted to a high wire outside of the mine, would not cause interference with trailing cars where the wire is low. These conditions have all been met in an extremely ingenious and simple manner as illustrated in Fig. 6, in which it will be noted that all working parts are exposed to view and are readily accessible. Furthermore, it should be noted that while the new trolley may be mounted on a small bracket it is also adapted to the standard base.

The new trolley has two principal parts between which is an intermediate base. This intermediate base may be swung from the operator's seat to either side or to the center of the locomotive and may also be adjusted for height. The upper section of the trolley pivots about this base and may be swung either to the forward or back positions for either direction of operation. The upper section of the trolley operates in the usual manner and will automatically follow the usual variations in height or slight lateral variations in the location of the trolley wire. Wide variations are taken care of by the lower section, which is adapted by the operator to special conditions.

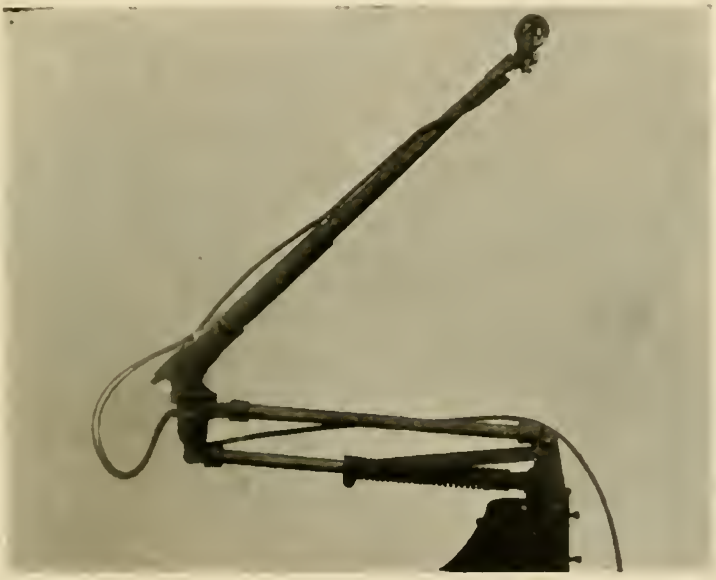


FIG. 6—TROLLEY FOR MINE LOCOMOTIVE

The rooms in which the actual mining is done are often not supplied with a trolley wire or with bonded rails. Two methods are in common use for drawing the cars out of these rooms after they have been loaded. By one method the locomotive is equipped with a motor driven traction reel and several hundred feet of wire cable. By this system the locomotive remains on the cross-entry at the entrance to the room and the cable is carried into the room and hooked to the cars which are to be drawn out. The cable is then reeled in and the cars drawn out to the locomotive. The traction reel has long been in use, but there have been recent improvements in the design of the various parts and in the arrangement of the apparatus so as to protect it from grit and for the protection of the operator.

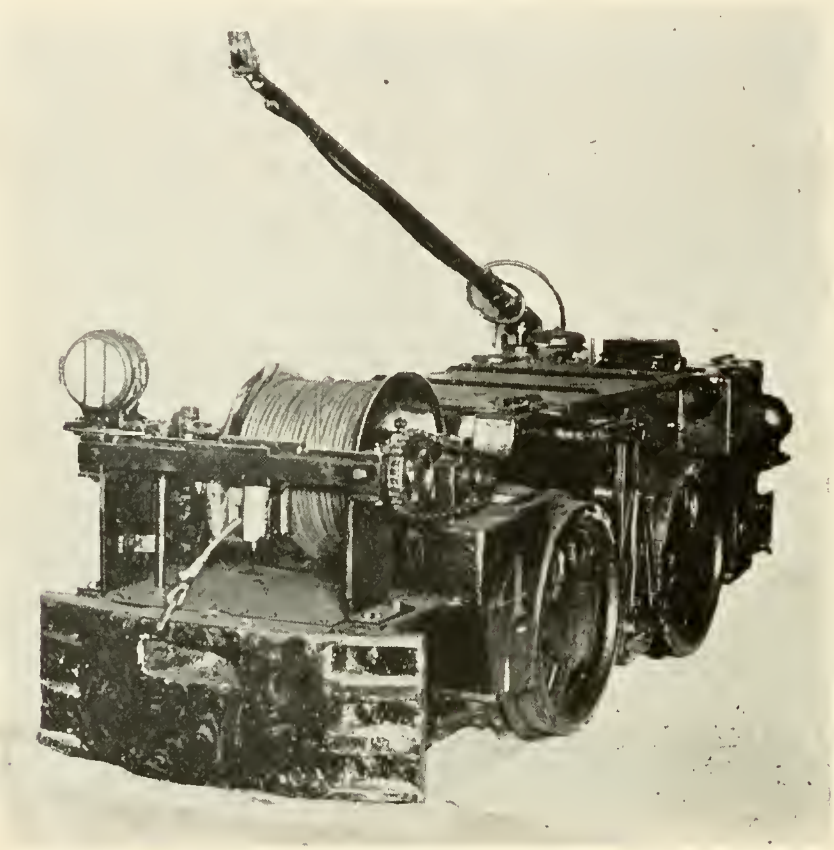


FIG. 7—SINGLE CONDUCTOR CABLE REEL ON GATHERING LOCOMOTIVE

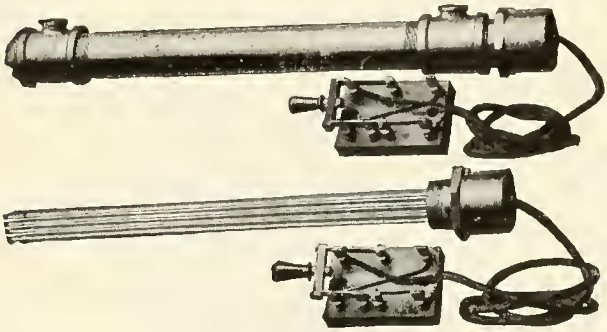
By the other system the locomotive is equipped either with a single or double conductor cable reel. The single conductor cable is used in mines where it is the practice to bond the rails in the rooms. By this system the end of the cable is hooked over the trolley wire, thus connecting the locomotive to the trolley, and the return circuit is obtained through the rails. If unbonded rails are used in the rooms, a double conductor cable reel is used and one end of the cable is hooked over the trolley wire and the other to the rail at the end of the bonded section of track. With either of these types of reels the locomotive is able to proceed into the rooms, reel-ing out the cable as it proceeds, and can handle both loaded and empty cars at the working face of the rooms. In order to handle this cable properly and prevent overrunning, the cable must be kept taut at all times and be reeled in as the locomotive returns out of the rooms. This is accomplished in a very effective manner by a driving chain and sprocket wheel on one of the locomotive axles. This operates through a cluch and friction plate and not only reels in the cable as the locomotive returns out of the room, but also actuates a spooling device which spools the cable regularly on the drum without piling it up and without damaging the insulation. By the use of this spooling mechanism it is possible to use a long drum of moderate diameter, and by mounting this drum horizontally on either the front or back end of the locomotive as shown in Fig. 7, there is but slight increase in the overall height and no interference with accessibility to all parts of the locomotive.

As may be seen from this brief description, the modern electric mine locomotive is radically different from the standard designs of a very few years ago. It is the product of an ever increasing market for this type of apparatus and has been developed not only to meet the increasing demands of power and space limitations, but also toward the end that it shall remain in service practically continuously under general operating conditions, and with no special equipment for maintenance other than that required to take care of the ordinary rolling stock about the mine.

HEATING POWDER HOUSES BY ELECTRICITY

W. O. PEALE

ELECTRICITY as a motive power in mining installations has so generally superseded steam-driven equipments that its use for this purpose is becoming almost universal, especially in those localities where coal is expensive and central station power relatively cheap. About the only other use for which a steam boiler may be employed is for supplying heat to the various powder storage houses which, for safety's sake, are usually located some distance from the mines. Where electric power is used for all other purposes, steam heat is expensive, requiring as it does a high initial investment in itself, the necessary pipe lines, and constant expenditures for fuel and the services of a fireman. Needless to say, this fact is sometimes a stumbling block in the path of the central station which is trying to add the mining company to its power load, as it is difficult to convince an operator that it will be economical to discard all his steam engine equipment for electric motor drive and yet maintain a boiler for heating purposes.



FIGS. 1 AND 2—BAYONET HEATER, WITH AND WITHOUT CASING

Electric heating of the powder houses provides a very efficient and inexpensive solution of the problem, being reliable, practically automatic and requiring no special attention. Any form of heating by direct flame is, of course, impracticable, direct air heating, even by the electric heater, being considered unsafe, so that the electric heater is used solely to heat the water for a hot water heating system. Heaters of the immersion type are used and they may be considered 100 percent efficient. Fig. 1 shows a heater in its casing and Fig. 2 the heating element. Heating is accomplished by the natural circulation of water through the casing surrounding the heater.

The application of this heater is a very simple matter, all that is needed being an expansion tank for a reserve water supply, a coil of piping inside the powder house, the necessary pipe fittings, and a few hours work. A diagram of the piping connections is given in Fig. 3. A small shed is built outside the powder house in which the heater and tank are installed with pipe connections to the heating coils inside. It would be possible to install this type of heater directly in the powder house, but as it is necessary to locate all fuses and switches outside, it is considered better to keep all wiring outside the building and thus avoid all possibility of danger resulting from a ground or short-circuit. The heating coils are of ordinary iron pipe, preferably not less than one inch in diameter, and should be arranged around three sides of the room. A pronounced slope should be given to the coils in order to eliminate air pockets and assist the natural circulation of the hot water. A pet cock at the highest point in the system provides a means for drawing off any air which may accumulate. This completes the installation and all that is necessary is to fill the system with water and close the switch. An adjustable ventilator is desirable to assist in regulating the temperature but is not absolutely essential.

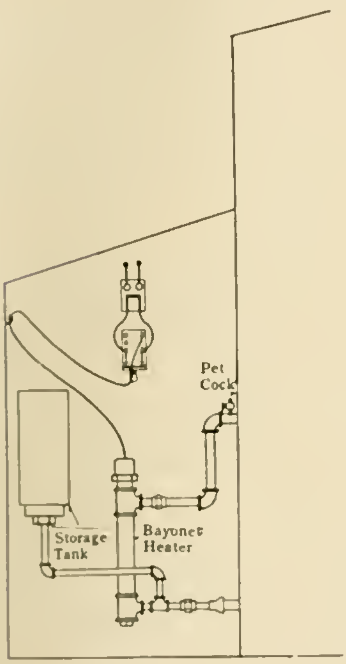


FIG. 3—PIPING DIAGRAM OF ELECTRIC HOT WATER HEATING SYSTEM

This method of heating was applied recently to a powder house, eight feet square by six feet, six inches high. The heater was of 1 800 watts maximum, 450 watts minimum, capacity. The house contained 3 000 pounds of frozen dynamite at a temperature of 22 degrees F. The high heat, 1 800 watts, was put on at 6 p. m. and left over night. At 6 a. m. the temperature in the house was 170 degrees F. The heater was then put on the low heat of 450 watts. This was sufficient to maintain a temperature of 85 degrees F. with outside temperature ranging from 22 degrees to 36 degrees F. Assuming an energy cost of 1.5 cents per kw-hr., the cost per day of 24 hours would be about 20 cents, a very small item as compared to the expense of a steam boiler and fireman.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM (Cont.)

BRAKES FOR ELECTRICALLY OPERATED TRAINS

WALTER V. TURNER and P. H. DONOVAN

THE TRIPLE VALVE

THE triple valve comprises three main portions, as shown diagrammatically in Fig. 11, the *equalizing portion,* the *emergency portion* and the *magnet bracket portion.*

The Equalizing Portion is made up of an equalizing piston *1* (with reduction limiting valve *4*), an equalizing slide valve *2* and graduating valve *3*, which directly control the pneumatic service application and indirectly the release of the brakes, and the charging of the auxiliary *63* and supplementary *62* reservoirs; a supplementary reservoir check valve *25,* which separates this reservoir *62* from the auxiliary reservoir *63* when a brake-pipe reduction is made; a service port check valve *24,* which prevents back flow of brake cylinder pressure to the face of the release piston when releasing the brake; a release piston *6*, which directly controls the release of the brakes; a safety valve *41*, which blows down the auxiliary reservoir pressure in an emergency application; a cut-off piston *21* and valve *22*, whice prevent main reservoir air from flowing to the safety valve and to the auxiliary reservoir during an emergency application; a direct and graduated release cylinder cap, which is to be placed in one position or the other, according as a graduated release of the brake is or is not to be provided for.

In the *emergency portion* are:—The quick action piston *11* and valve *12,* by means of which brake-pipe air is vented to the atmosphere in emergency; the pilot valve *19,* which vents air from the back of emergency valve in emergency application; the emergency valve *16,* which, when open, admits main reservoir air *107* direct to the brake cylinder via *90;* the emergency slide valve piston *7* and slide valve *8,* which control the charging of the quick-action chamber and the quick-action closing chamber, the flow of air from the quick-action chamber to the cut-off valve piston, the flow of air from the quick-action closing chamber to the quick-action piston *11* and the emergency switch piston *14* in the magnet bracket portion (via opening *102*), the flow of air to the face of pilot valve piston *18,* venting of air from the face of cut-off valve piston and opening of the quick-action chamber maintaining port; the protection valve *9,* which automatically produces quick action when the brake pipe pressure is reduced to a predetermined value.

In the *magnet bracket portion* are:—The emergency switch *15*, which is closed at the same time the quick-action valve *12*, emergency portion, is opened (by air from the quick-action closing chamber); the service application magnet *32* and valve *33*, by means of which the service brake pipe reduction is made at each car; the release magnet *29* and valve *30*, which control the electric release of the brake; the emergency magnet *35* and valve *36*, which causes the quick-action parts to operate by venting air from the face of the emergency slide-valve piston *7* to atmosphere; the magnet valve cut-out cap *38*, by means of which any or all of the application magnets may be cut out or cut in.

OPERATION OF TRIPLE VALVE

Charging position—Air from the brake pipe enters at *42* and *43*, and flows to the chamber *A* and the face of the equalizing piston *1*, moving it to release position, thence through the feed groove *120* to the slide-valve chamber *B* and to the auxiliary reservoir *63*, and also through *56* past supplementary reservoir check valve *25*, thence through *57, 58, 62* to the supplementary reservoir and through *57, 59, 60, 61*, chamber B and *63* to the auxiliary reservoir through the equalizing slide valve. The auxiliary reservoir is thus charged from two sources. Brake-pipe air also flows to the under side of the quick action valve. Air from the brake pipe also acts directly on the lower seat of the protection valve *9*, *through port 42*, which will remain seated downward until a certain predetermined pressure is reached (governed by the protection valve spring), when it will move very quickly to its closed position, owing to its differential areas, and to the fact that the space at the back of the protection valve is always open to the atmosphere.

With the protection valve closed, the brake-pipe air will flow past this valve through *45* to chamber *C* and the face of the emergency side-valve piston *7*, forcing the latter to its release position (if not already there), and then to chamber *D* through groove *106*, and charging the quick-action chamber through *113* and the quick-action closing chamber through *91*. Air from *D* also flows through *94* to *93* to chamber *18* (near the safety valve) on the face of the cut-off portion *21*, pushing the latter to its seated position in which the cut-off valve *22* is held open.

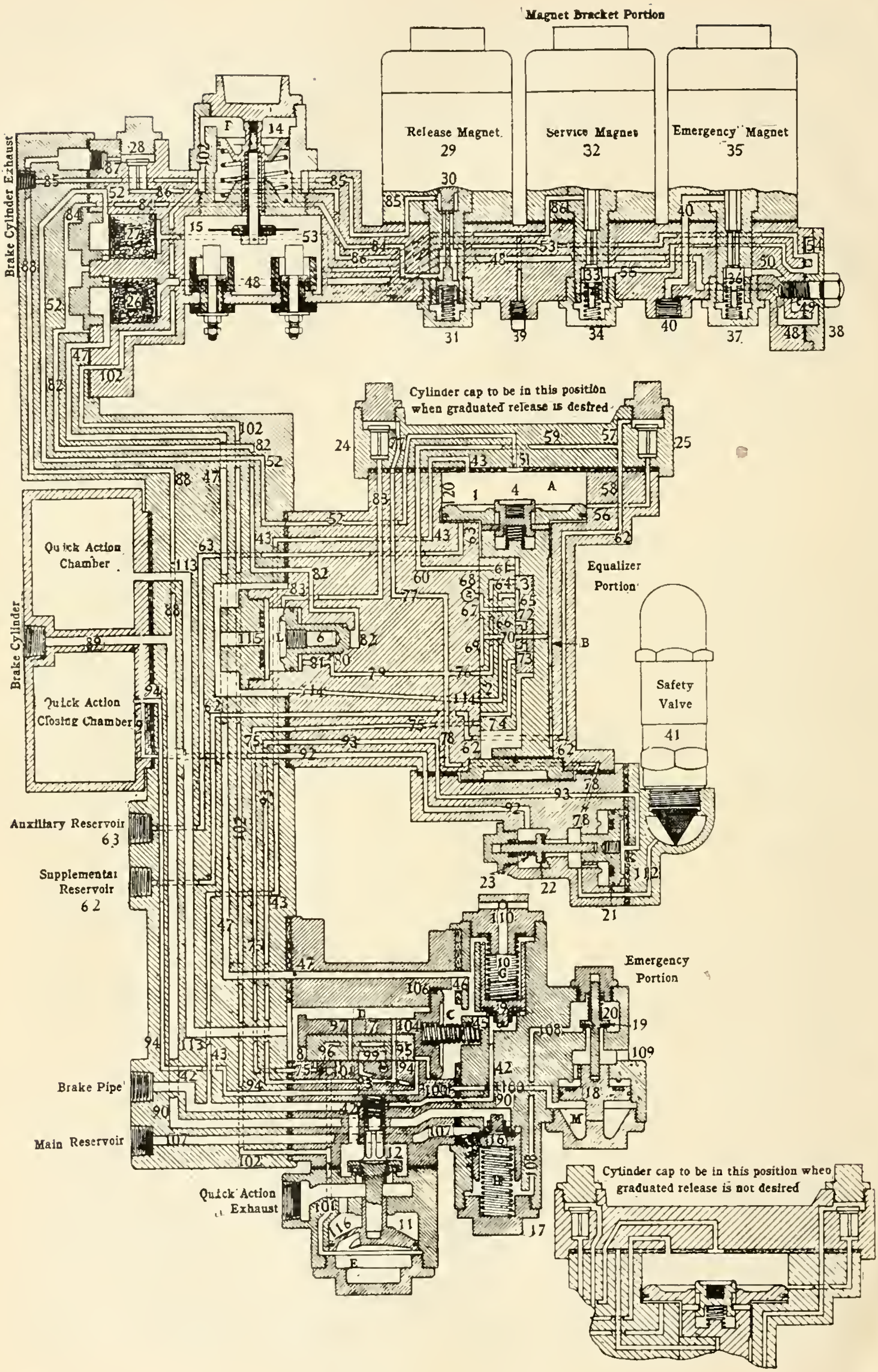


FIG. 11—SCHEMATIC DIAGRAM OF TRIPLE VALVE

The brake pipe is also in communication with the emergency application magnet valve *36* by way of the protection valve *9* through *42*, *45*, *46*, *47*, strainer *26*, *48*, *49*, *50* (the magnet valve cut-out cap being in its normal position).

The chamber *A* on the face of the equalizing piston *1* is in communication with the service application magnet valve *33* by way of *51*, *52*, strainer *27*, *53*, *54*, magnet-valve cut-out cap *38* and *55*.

ELECTRIC SERVICE APPLICATION

When the operator moves the brake-valve handle to the application position the lap position of the valve is passed over, in which position the release circuit magnet is closed, thus energizing this magnet *29* and seating the release magnet valve *30*, which is held closed in service position also. The service application magnet circuit is closed at this time, energizing magnet *32*, which in turn opens the service application magnet valve *33*. This allows air to flow from chamber *A*, through *51*, *52*, strainer *27*, *53*, *54*, *55*, *86*, check *28*, *87*, *88* to the brake cylinder (or directly to the atmosphere, if desired). The electric service application port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston *1*, graduating valve *3* and equalizing slide valve *2* to move over to service position; but this rate of reduction is not rapid enough to move the emergency piston *7* and slide valve *8*, since under these conditions the quick-action chamber pressure can reduce through its feed groove *106*, as rapidly as the brake-pipe pressure is being reduced. This insures the desired service application and prevents the possibility of undesired quick action.

The first movement of the equalizing piston *1* and graduating valve *3* toward service position closes the graduated release port *61*, and opens the service port *74* through the slide valve *2*, which, however, has not yet moved so as to cause this port to register with port *114*. The first movement of the equalizing piston *1* and graduating valve *3* also connects, through cavity *65*, in graduating valve *66* (which leads through *114* to the face of the large end of release piston *6*), with port *64*, which leads through *76*, *70* and *81* to the back of the release piston, thus balancing these pressures, and since the small end of this piston is connected to the atmosphere, through *82*, *84*, past valve *30* and port *85*, it will be forced to its closed position, due to the differential areas. Also this first movement of the piston *1* and graduating valve *3* opens the resistance increasing cavity *69* in the face of the equalizing slide valve *2* to atmospheric pressure, via *70*, *73*, *72*, *67* and *68*. This increase in amount of the under surface of the slide valve *2*, which is exposed to the atmosphere, increases the resistance which must be overcome before the equalizing slide valve *2* can be moved. The object of this is two-fold:—First, to reduce the sensitiveness of the valve sufficiently to prevent fluctuations in brake-pipe pressure, due to the feed valve or other causes, from producing undesired light service applications or brakes creeping on. Second, to insure the making of such a brake pipe reduction in applying the brakes that no trouble in releasing can result from inability to establish sufficient differential, as may be the case where the brakes will apply on a very light brake pipe reduction. It will be noted that the first movement of the equalizing piston *1* in returning toward release position disconnects the resistance increasing cavity *69* from the atmosphere and reëstablishes its communication to the auxiliary reservoir, so that the added resistance to motion is at once eliminated, and the valve will consequently be easier to release than to apply.

When sufficient differential has been established to cause the equalizing piston *1* to move the slide valve *2* to its service position, the opening of the service port *114* permits auxiliary reservoir air (which is always present in chamber *B*), to flow past the graduating valve *3* and through the slide valve via *74*, to the brake cylinder through *114*, *115*, past the release piston *6* through port *83* past service port check valve *24*, ports *77*, *78*, past cut-off valve *22* and through *92*, *91* and *89*. The brake cylinder pressure will continue to be increased in this manner until it equalizes with the auxiliary reservoir, or (in case a full service reduction in brake pipe pressure is not made) until the auxiliary reservoir pressure is reduced to a point slightly lower than the pressure in the brake pipe. In the latter case the equalizing piston *1* and graduating valve *3* will move back until the piston stops against the slide valve *2* in service lap position, the graduating valve then closing the service port *74* and preventing further building up of brake cylinder pressure and at the same time opening the resistance increasing port *70* to auxiliary reservoir pressure, thus again balancing the slide valve *2* so far as port *70* is concerned and rendering it easier to release than it was to apply.

The service application magnet *32* may be held energized, thus holding the service application magnet valve *33* open and causing a continuous brake pipe reduction, which permits the auxiliary and brake cylinder pressure to equalize, giving a full service application of the brakes, or, it may be energized for shorter periods of time, thus causing partial brake applications to any desired degree, after which the parts will move to service lap position, as above mentioned. This energizing of the service application magnet *32* may be repeated as many times as desired, each time causing an increase in brake cylinder pressure, corresponding to the amount of brake pipe reduction, until equalization takes place.

It will be noted that the air flowing to the brake cylinder by way of ports *78* and *92* (cut-off valve *22* being then open) is also free to flow to the safety valve by way of port *112*. This safety valve performs no function during service operation, however, since it is set for 60 lbs. and the equalization pressure of the auxiliary reservoir and brake cylinder is but 50 lbs. (70 lbs. brake pipe pressure being carried with this equipment).

REDUCTION LIMITING FEATURE IN THE EQUALIZING PISTON

Ordinarily, the service magnet valve makes a brake pipe reduction by connecting the brake pipe to the brake cylinder—this then means that these two pressures are approaching each other, and as they near equalization the rate of reduction in the brake pipe is gradually decreasing to zero. In order to procure the desired pressure in the given time, then, the rate of reduction at first is quite rapid and the margin between it and the emergency rate is very small, this margin being broadened as equalization is approached.

When it is desired to have a uniform margin between the service and emergency rates of brake pipe reduction, the service magnet connection to the service brake cylinder may be closed and opened to the atmosphere by taking out plug *39* (in the magnet section) and inserting it in the opening between ports *87* and *88*. In order to limit the brake pipe reduction to the equalization point under these circumstances, the reduction limiting check valve *4* is embodied in the equalizing piston *1*. When the service magnet valve *33* is open, and the equalizing piston *1* is moved over toward service position, the reduction in auxiliary reservoir pressure which follows the opening of the service port stops the movement of the equalizing parts before the reduction limiting check valve seats against the cylinder cap gasket.

If a continuous brake pipe reduction is made the equalizing parts will remain in this position until the auxiliary reservoir and brake cylinder pressures have equalized; then a further reduction in brake pipe pressure will cause these parts to be moved by the higher auxiliary reservoir pressure, until the reduction limiting valve seals against the cylinder cap gasket, thus separating ports *43* and *51*, and preventing an over-reduction in brake pipe pressure.

ELECTRIC EMERGENCY APPLICATION

With the brake valve handle in emergency position, the emergency application magnet circuit is closed, energizing magnet *35*, which in turn opens the emergency application magnet valve *36* and allows air from the brake pipe to flow to the atmosphere through ports *42*, *45*, *46*, *47*, strainer *26*, *48*, *49*, *50*, past valve *36* and through port *40*. This opening past the emergency application magnet valve *36* to the atmosphere is of such size as to permit of a rate of brake pipe reduction which will cause the emergency slide valve piston *7* and its slide valve *8* to move to emergency position, and also the equalizing piston *1*, graduating valve *3* and equalizing slide valve *2* to move over until the piston *1* rests against the cylinder cap gasket.

With the equalizing piston *1*, graduating valve *3* and slide valve *2* in emergency position, the auxiliary reservoir is connected to the safety valve *41*, the same as in service operation, through ports *74*, *114*, *115*, chamber *L*, port *83* past valve *24*, port *77*, *78* and *112*. Consequently, the auxiliary reservoir pressure will be reduced by the safety valve to the point at which the latter closes, viz., 60 lbs. This reduction of auxiliary reservoir pressure when an emergency application is made insures that the brake can easily be released thereafter.

With emergency slide valve *8* in emergency position, air flows from the quick action closing chamber through ports *94*, *95*, *96* and *101* to chamber *E*, thus forcing the quick action valve *12* open, thereby venting brake pipe air to the atmosphere (which causes a sudden local brake pipe reduction that starts pneumatic quick action), and also through port *102* to chamber *F* (in the magnet section), closing emergency switch *15*, holding the emergency application magnet circuit closed. This serves as a circuit closer to cause (electrically) instantaneous quick action throughout the train when originating pneumatically.

The quick action valve *12* will remain open and emergency switch *15* closed, until the quick action closing chamber drains by way of the quick action exhaust to the atmosphere, through the small drilled port *116*, in quick action piston *11*. Also in this position of the emergency slide valve *8*, port *93* leading to the face of the cut-off valve piston *21* is connected to the atmosphere through cavity *99* in the slide valve, venting air from chamber *K* on the face of cut-off valve piston and thus the cut-off valve will be closed by its spring *23*. Also air flows from the quick action chamber through port *113* and chamber *D*, thence through the emergency slide valve ports *97* and *100* to chamber *M* on the face of the pilot valve piston *18*, thus opening pilot valve *19* and venting air from the back of the emergency valve *16* to the atmosphere through ports *108* and *109*. Since main reservoir pressure, through port *107*, is exerted on the face of the emergency valve *16*, this valve will then be forced open very quickly, allowing main reservoir air to flow direct to the brake cylinder through ports *107*, *90* and *89*. The cut-off valve *22* being closed prevents main reservoir air flowing to the safety valve *41* or to the auxiliary reservoir, thus giving full main reservoir pressure in the brake cylinder.

A connection is also made in this position from the quick action chamber through port *113*, chamber *D*, port *75* to chamber *B* and the auxiliary reseroir through port *63*. Then the air in the auxiliary reservoir is made to maintain the quick action chamber pressure (since its volume is quite small), against possible leakage past the pilot valve piston *18*, thus insuring that the pilot valve *19* will remain open, thereby maintaining the high brake cylinder pressure in emergency.

ELECTRIC RELEASE AFTER SERVICE APPLICATION

When it is desired to release the brake, the brake valve handle is moved to release position, in which the release magnet circuit is open, and magnet *29* is de-energized, allowing the release magnet valve *30* to be opened by its spring *31*. The brake pipe charging port in the brake valve is also open, restoring the air in the brake pipe to its initial pressure. This increase in the brake pipe pressure forces the equalizing piston *1*, graduating valve *3* and equalizing slide valve *2* to release position in which the brake cylinder air is exhausted to the atmosphere, through ports *89*, *91*, *92*, past valve *22*, through ports *78*, *79*, *80*, *82*, *84*, past valve *30* and through *85* to exhaust. If the brake valve is allowed to remain in this position, the brake cylinder air will be exhausted in thhe shortest possible time.

ELECTRIC RELEASE AFTER EMERGENCY APPLICATION

After an emergency application has been made the quick action valve *12* will remain open and the emergency switch *15* closed, until the quick action closing chamber air has drained to the atmosphere.

through the small drilled port *116* in quick action position *11*. The quick action valve *12* and emergency switch *15* will then be returned to their normal position by their respective springs.

With the quick action valve *12* closed and the brake pipe pressure being restored, the protection valve *9* will be the first to go to its normal (release) position, which will in turn admit air to the face of the emergency slide valve piston *7*, forcing it to release, and charging quick action and quick action closing chambers, as described under "Charging." Brake pipe pressure has also been built up on the face of the equalizing piston, forcing it with its valves to release position. With emergency slide valve *8* in release position, chamber *M* is connected to the atmosphere, through port *100* and cavity *99*. Pilot valve *19* will then be closed by its spring *20*. Emergency valve *16* will remain open until the pressures on the front and back of this valve have equalize dthrough the small port *121*, when it will be closed by its spring *17*. Quick action chamber air also flows to the face of cut-off valve piston *21*, through ports *104* and *93*, thereby opening cut-off valve *22* and allowing the exhaust of the high pressure cylinder air past the cut-off valve *22*, small end of release piston *6*, and the release magnet valve *30* in the magnet position.

GRADUATED RELEASE

The release of the brake may be graduated by moving the brake valve handle back and forth between release and lap positions. The brake pipe charging port of the brake valve is open in release position. Therefore, the equalizing parts of the triple valve will be moved to release position. In this position cavity *65* in the graduating valve *3* connects chamber *L* to the atmosphere, through ports *115*, *114* *66*, *67* and *68*. The release piston *6* will then be forced open, due to the brake cylinder pressure on the back of same. In release position of the brake valve, the release magnet circuit is open; magnet *29* is then de-energized and release magnet valve *30* is thus held open by spring *31*. Brake cylinder air can then flow to atmosphere, past the cut-off valve, small end of release piston and release magnet valve. But when the equalizing slide valve *2* is in release position and the direct and graduated release cylinder cap in the position marked "Graduated Release" the graduated release port *61* is open, which connects the supplementary and auxiliary reservoirs. The former volume was not used in service operation and will still have its initial pressure. The supplementary reservoir air flowing back into chamber *B* and to the auxiliary reservoir will, therefore, quickly raise the pressure in the latter to a point which is slightly in excess of that in the brake pipe, and consequently the equalizing piston *1* and graduating valve *3* will be moved to graduated release lap position, if the graduated release port is closed. But the cavity *65* in the graduating valve *3* connects ports *64* and *66* leading to the back and to the face of the large end of release piston *6*, thus balancing these pressures. This piston will then be forced to closed position, due to the differential areas, cutting off the release of air from the brake cylinder. No further release of brake cylinder air can now be made until the brake pipe pressure is again increased and equalizing piston *1* and graduating valve *3* are moved back to release position.

Even with the direct and graduated release cap in "Direct Release" position, which cuts out the supplementary reservoir connection through ports *59, 60* and *61* to the auxiliary reservoir, it is always possible (when the electric features are operative) to graduate the release of brake by means of the release magnet valve *30* alone, if the brake valve handle is moved back and forth between release and lap positions.

PNEUMATIC OPERATION

In case any of the electric features should be inoperative, through loss of current of other cause, the triple valve may be operated as any of the older types, the brake pipe reductions then being made by means of the brake valve alone, the brake valve handle being the same for both electric and pneumatic operation.

Pneumatic Service Application—With the brake valve handle in service position, the preliminary exhaust port in the brake valve is opened, allowing the equalizing piston to lift and cause a rate of brake pipe reduction sufficiently rapid to move the triple valve equalizing piston, graduating and slide valves to service position. The rate of reduction as fixed by the brake valve is, however, not as rapid as that at which the quick action chamber pressure can be reduced through its feed groove into the brake pipe, thus positively guarding against undesired quick action. The flow of air from the auxiliary reservoir into the brake cylinder is the same in pneumatic as in electric service operation.

Pneumatic Emergency Application—With the brake valve handle in this position, the brake valve emergency exhaust port is open and permits such a rapid rate of brake pipe reduction that the quick action chamber pressure cannot reduce as rapidly through its feed groove as the brake pipe pressure is being reduced through the brake valve. Consequently, the emergency slide valve piston *7* and its slide valve *8* are moved to their emergency positions. The equalizing piston *1* has also moved (carrying with it the slide valve *2* and graduating valve *3*) against the cylinder cap gasket. The operation of the various valves is now the same as previously described under "Electric Emergency Application."

Pneumatic Graduated Release—This is accomplished in the same manner as previously described, except that the release magnet valve *30* is open at all times, and the graduated release controlled entirely by the release piston *6*.

Protection Feature—In case there is excessive leakage, after a full service application has been made, which will reduce the brake pipe pressure to a certain pre-determined point, the protection valve *9* will be forced open by its spring *10*, thus connecting the face of the emergency slide valve piston *7* to the atmosphere, through port *46*, chamber *G*, and port *110*, producing a rate of brake pipe reduction that will cause emergency piston *7* and slide valve *8* to move to emergency position, thus causing quick action as previously described.

SHOP TESTING OF ELECTRICAL APPARATUS

III—INSULATION TESTING

THE general purpose in shop insulation testing is to determine the fitness of the apparatus to perform its function under abnormal as well as normal voltage conditions. A complete insulation test, such as is made on electrical machinery before being sent out from the factory, involves a large number of tests of individual parts before the apparatus is assembled, as well as a final test of the completed machine. In making the final insulation test, the aim should be to reproduce in the apparatus as far as possible the actual conditions, such as temperature and humidity, under which the apparatus will operate. Since high voltage insulation tests, especially those in which a voltage greatly in excess of the normal is used, tend to weaken the dielectric strength of the insulation each time they are made, care should be taken to avoid subjecting the apparatus to unnecessary electrical stresses, by making as few such tests as possible even on new machines.

INSULATION RESISTANCE

The measurement of insulation resistance is frequently a considerable aid in giving an indication of the condition of the insulation in regard to moisture. On this account it is often advisable to take a rough measurement of the insulation resistance either by the voltmeter method or the megger. Should the value of the resistance obtained be abnormally low, the insulation is probably moist, and the resistance should be brought up to its normal value (at least one megohm per 10 000 volts test voltage) before a breakdown test is applied. When the moisture in the winding is finely sub-divided, the resistance may appear very high and yet the apparatus contain sufficient moisture to cause it to break down in service. The resistance of insulation changes very rapidly with change of temperature, and this should be taken into account when taking resistance measurements.

For perfectly dry homogeneous material the shape of insulation—temperature curves is in general that indicated by the full line in Fig. 1. The temperature coefficient is negative with a logarithmic characteristic. This shape of curve is, however, practically never secured in actual practice, as nearly all insulation contains a certain amount of moisture at ordinary temperatures. A curve of this type** is ordinarily taken only when there is reason to suspect moisture and, as the temperature can only be raised gradually, the time element must also be considered. A temperature—resistance curve, of which the dotted line Fig. 1 is typical, must be considered therefore as including time and moisture characteristics, the resistance decreasing as the temperature increases until a quite low minimum is reached. As the machine dries out, the insulation resistance increases rapidly, reaching a maximum at a temperature of 80 to 100 degrees C., at which point very little moisture remains. If the temperature is still further increased, the resistance begins to decrease again, following roughly the logarithmic curve, until the charring of the insulation causes the resistance to decrease rapidly. Since so many variables enter into the problem, it is impossible to duplicate any actual curves, and only general characteristic curves can be shown. The usual method of heating is to pass a current through the winding.

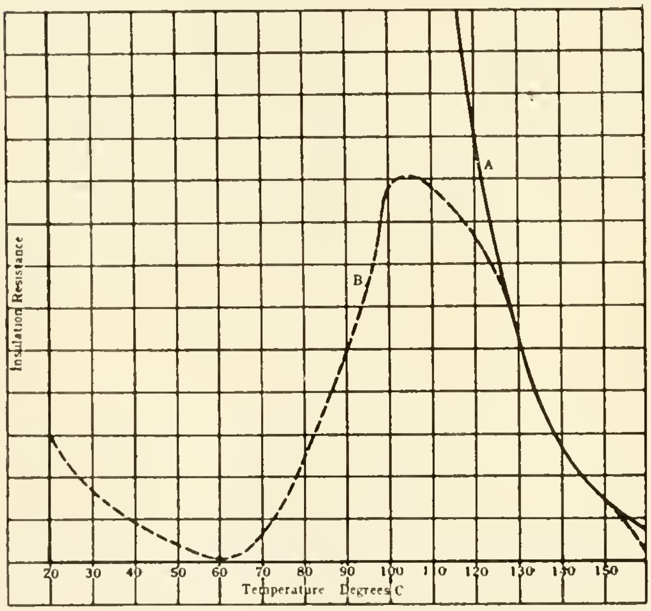


FIG. 1—TYPICAL INSULATION CHARACTERISTIC CURVES

Heating of the insulation also takes place when a high voltage is applied due to the I^2R loss in the insulation.* With moderate stress the temperature rises gradually at first and then more slowly and then becomes constant, depending on the facility with which the material can dissipate its heat and on the temperature of the surrounding medium. As the stress is increased, a point is finally reached where the heat is developed faster than it can be dissipated. Hence the temperature increases until the insulation breaks down. If the material is not thoroughly dried, the temperature rises much more rapidly than in a well dried stock. The heat tends to dry out the material and in this case the temperature may actually decrease.

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*See paper before the A. I. E. E., June, 1902, by Mr. C. E. Skinner.

**The general formula is $\text{Log}\ (R_t \div R_T) = (D - Ct)\ (T - a)$ where t=the temperature of observation, T=any standard temperature, R_t=the resistance at temperature t, R_T=the resistance at temperature T, C & D are constants which are different for different materials. See paper by Mr. Townsend Wolcott, before the A. I. E. E., June, 1902.

If appreciable time elapses before breakdown, the final breakdown in fibrous material results usually from the burning of the material and not through mechanical rupture. In numerous tests which have been made, the material has been found to be badly charred on the interior without breakdown having resulted. In such cases the insulation is badly damaged without any indication being shown during the test.

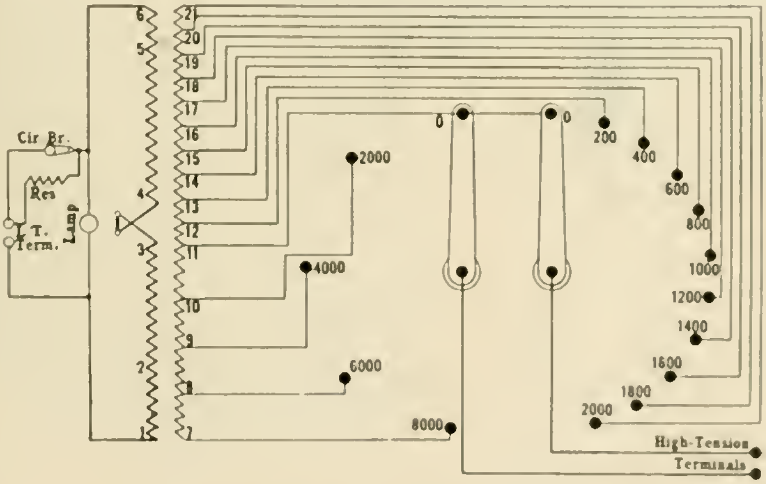

FIG. 2—WIRING DIAGRAM OF A SMALL PORTABLE INSULATION TESTING TRANSFORMER

The Standardization Rules of the American Institute of Electrical Engineers give the following as a standard for insulation resistance: "The insulation resistance of complete apparatus should be such that the rated voltage of the apparatus will not send more than one-millionth of the rated load current through the insulation. Where the value found in this way exceeds one megohm, it is usually sufficient."

DIELECTRIC STRENGTH

By far the most important property of the insulation of electrical machinery is its resistance to rupture by electrical stress, or its dielectric strength, and tests of the dielectric strength constitute the major portion of insulation testing. For these tests certain standard voltages are specified, depending on the rated terminal voltage of the apparatus and, in some cases, on its kilowatt capacity.

For machines having a rated terminal voltage of 2,500 volts or over, the test voltage is double the terminal voltage, while for apparatus with a lower rated terminal voltage, the test potential depends both on that voltage and on the rated output. The reasons for these variations in requirements are largely mechanical, as insulation sufficient for electrical purposes on machines of comparatively low voltage does not always possess mechanical strength to insure safety against vibration and abrasion. Low voltage apparatus is also in much greater danger of being subjected to potentials greatly in excess of those for which it was designed than high voltage machinery. Table I, taken from the Institute Standardization Rules, gives the testing voltages specified for all classes of machinery. In all cases the testing voltage is to be applied for one minute continuously.

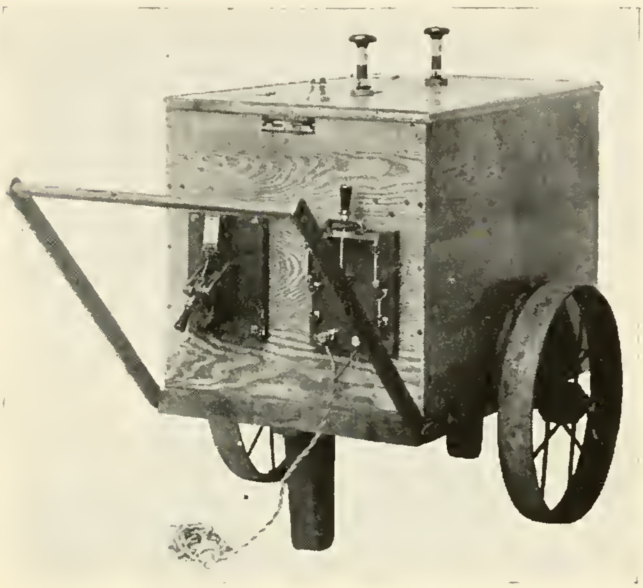

FIG. 3—SMALL PORTABLE INSULATION TESTING SET
For voltages up to 10 000 volts.

TABLE I—STANDARD FINAL TEST VOLTAGES

Rated Terminal Voltage of Circuit	Rated Output	Testing Voltage
Not exceeding 400 volts	Under 10 kw	1 000 volts
	10 kw and over	1 500 volts
400 volts and over, but less than 800 volts	Under 10 kw	1 500 volts
	10 kw and over	2 000 volts
800 volts and over, but less than 1 200 volts	Any	3 500 volts
1 200 volts and over, but less than 2 500	Any	5 000 volts
2 500 volts and over	Any	Double normal voltage

The method of obtaining the testing voltage varies considerably with the class of apparatus to be tested and the voltage used. Where large capacity is not required, portable testing sets furnish the most convenient means of obtaining the proper voltage. These sets consist of a transformer enclosed in a box and mounted on wheels so as to be easily movable; a circuit-breaker, pilot-lamp and knife-switch are usually included in the primary circuit. The high-tension winding of the transformer consists of two coils in series, from both of which leads are tapped off at intervals corresponding to the voltage steps indicated by dials on the cover of the box. It is thus possible to obtain a great number of steps between zero and maximum voltage. A wiring diagram for a five kilowatt, 220—10 000 volt testing set* is shown in Fig. 2. The great disadvantage of these sets lies in the method of controlling the voltage, as the secondary circuit must be broken and re-established each time when passing from step to step, and no method of gradually changing either primary or secondary voltage is afforded. For this reason, testing transformers of larger capacity and higher potentials are provided with Stilwell or induction type regulators in the primary circuit, so that the voltage can be increased or decreased gradually by varying the current in the primary or low-tension winding.

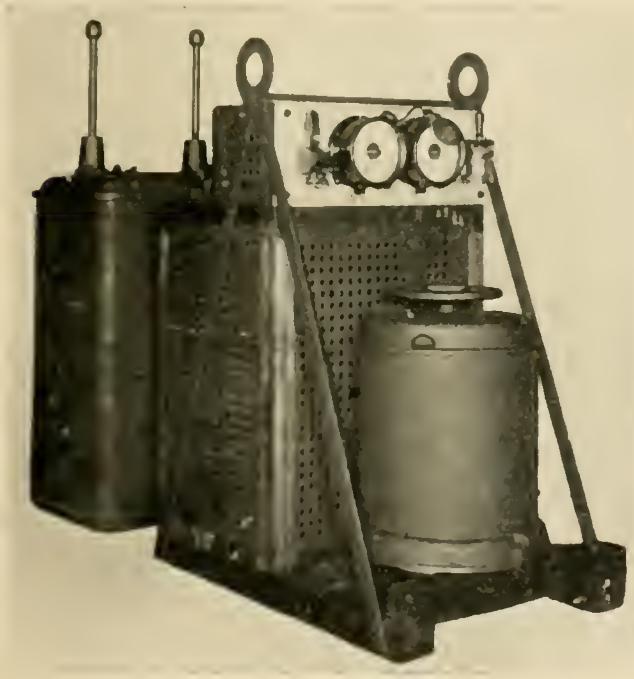

FIG. 4—INSULATION TESTING SET
Equipped with induction regulator for gradual voltage increase.

There are several methods of measuring the testing voltage, viz.: by means of (1) an ordinary voltmeter in series with the proper amount of resistance, (2) an electrostatic voltmeter, (3) a spark-gap, or (4) in the case where a regulator is used to vary the low-tension voltage, by connecting a voltmeter across the low-tension terminals; then, since the ratio of transformation is fixed, the high tension voltage may be read directly from the voltmeter. This last method is by far the most satisfactory one but is not very accurate for high voltages, nor for machines of high static capacity, in which case the secondary voltage may be quite different from that indicated by the ratio of transformation. The first method consumes considerable power when the capacity of the transformer is large, and the spark-gap method is unreliable when the sparking distance is less than half an inch. As the voltage increases, the needle spark-gap gives correspondingly better results up to about 100,000 volts. A calibration curve for a needle spark-gap is given in Fig. 5. The indications are affected by atmospheric conditions, and it is necessary to use new needle-points for each discharge. For these reasons, the needle spark-gap is used mostly as a check on other methods. The electrostatic voltmeter gives fairly satisfactory results, but the instruments are expensive.

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*See also article by Mr. C. S. Lawson in the JOURNAL for August 191 Vol. VIII, p. 723.

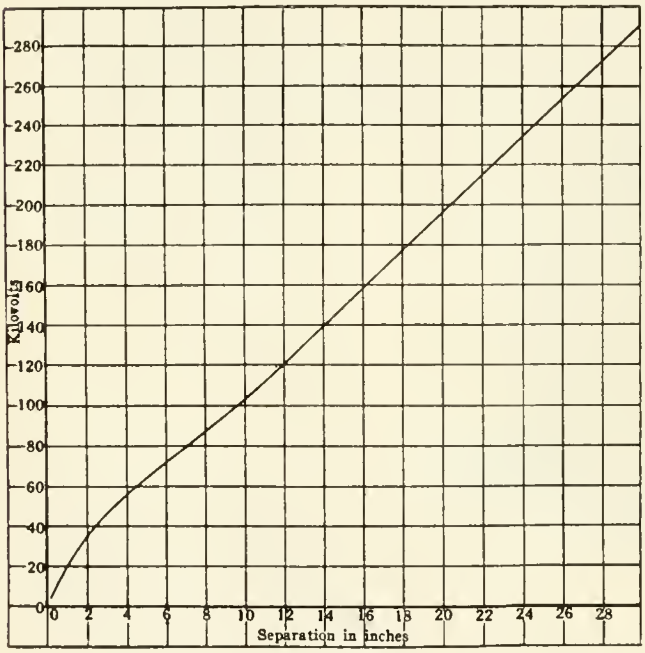

FIG. 5—NEEDLE SPARK GAP CALIBRATION CURVE

A method of spark-gap measurement has been developed and used in practical testing for about two years which possesses many advantages over the needle-point method now considered standard. In this method, two accurately machined spheres placed one above the other are used for the terminals of the gap instead of the usual needle-points. Experience has shown that the sphere-gap gives far more consistent and reliable results than can be obtained with needle-points. When the voltage used exceeds 100 000 volts, it becomes increasingly difficult to obtain consistent results with needles. The relation between separation of points and break-down voltage is affected to such an extent by conditions of atmospheric pressure, humidity, proximity of neighboring bodies, etc., that the values obtained by different investigators at different times vary considerably. The sphere-gap is little affected by external conditions, occupies a comparatively small amount of space, and is readily movable. The same spheres may be used almost indefinitely. Further, it has been found that as long as no brush discharge takes place, very consistent results are obtainable, and brush discharge will not occur when the spheres are separated by a distance less than their diameter. Hence, by using different sizes of spheres, the voltage range may be varied as desired. With spheres 50 cm (19.7 inches) in diameter, and the middle-point of the high-tension winding grounded, voltages up to 650 000 volts have been used with satisfactory results. The approximate relation between break-down voltage and air-gap obtained with two ten-inch spheres, one of which was grounded, is shown in Fig. 6. In view of the consistency and convenience of this method compared with the use of needle-points, it seems likely that it will soon supersede the latter as a standard.

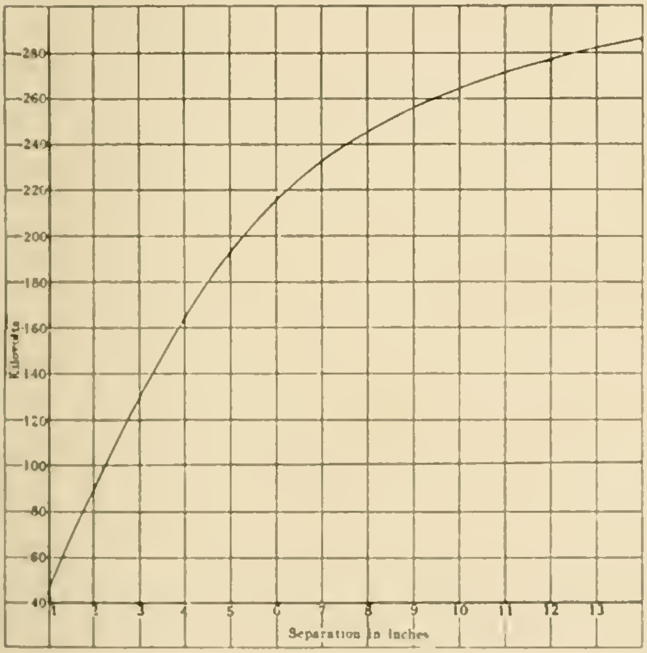

FIG. 6—SPHERE SPARK GAP CALIBRATION CURVE
10 inch spheres, one sphere grounded.

It is very necessary that the capacity of the testing transformer be sufficiently large to supply charging current for the apparatus in test without material distortion of the wave form or drop in voltage. If the static capacity of the apparatus in test is known the capacity of the transformer can easily be calculated, but as this static capacity is very seldom known, it is customary to build these testing transformers of a size sufficient to test almost any ordinary electrical apparatus. The testing capacity required for standard generators and motors is shown in Table II.

The breakdown tests which are given to the various component parts of electrical apparatus usually exceed those which the standard test of the complete machine imposes on any of its component parts. In a large generator, for instance, the individual coils are first tested for breakdown between turns and then for breakdown between conductor and a tin foil sheet representing the slot, before the coil is placed in a machine. After being assembled, the individual coils are tested for breakdown to ground before they are connected. After the coils are connected, the windings are again tested for breakdown to ground and from phase to phase before the machine is ready for its final complete test. The voltages to which the parts are subjected vary considerably with different types of apparatus, but are in general as indicated in Table III for direct-current machines and in Table IV for alternating-current machines. Some of the tests on component parts are specified as momentary tests and others for one minute. Usually the momentary tests are not considered as satisfactory as a test for one minute and are not used for final tests, but where a large number of tests are being made, as for instance individual coils, too much time is consumed in making one minute tests.

TABLE II—TRANSFORMER CAPACITY NECESSARY FOR INSULATION TESTING

Maximum Test Voltage	Capacity in Kilowatts
2 000	1
6 000	3
10 000	5
30 000	30
50 000	50
100 000	100
150 000	150
250 000	250

In addition to the tests of dielectric strength of insulation, short-circuit, open-circuit and ground tests are also made in order to reveal any faults in the insulation, or any damage which it may have received in handling. These tests are made on each individual armature coil before it is placed in position, and then on the completed armature. For this purpose special apparatus has been designed, consisting of a special type of transformer for coils, and of an alternating-current magnet for arma-

TABLE III.—TEST VOLTAGE FOR INSULATION TESTS OF DIRECT-CURRENT MACHINES AND ROTARY CONVERTERS

	Before Coils or Commutator are Placed on Rotor		Assembled Rotor		Assembled Field
Rated Terminal Voltage	Between Adjacent Turns in Coil	Between Adj. Commutator Bars	Comm. to Ground	Complete Armature Insulation	Field Coils to Ground
	Momentarily	Momentarily	Momentarily	One Minute	Momentarily
400 and less	100 volts	400 volts	3 000 volts	1 500 volts	2 500 volts
401-800	100 volts	400 volts	4 000 volts	2 000 volts	3 500 volts

tures which greatly simplifies the process of locating faults, either short-circuits or open-circuits. The transformer is built in the form of an E-shaped magnetic circuit, the middle section of which is wound with an exciting coil. On the back of the E, between the middle section and either outside section, are wound two small coils of several turns, the ends of the coils being connected to a telephone receiver, as shown in Fig. 7. The coils are so connected that under ordinary conditions the e. m. f's induced in them oppose each other and balance accurately. The armature or field coil to be tested is placed over one of the outside sections. If the insulation is perfect no current can flow in the coil and the e. m. f's in each half of the telephone circuit will balance. If, however, the coil is short-circuited, a current will flow, which will react on the magnetic field, and disturb the balance of the flux in the two magnetic circuits. Consequently a current will flow in the telephone circuit, which is indicated by a buzzing sound in the telephone receiver.

For large coils, a somewhat different method is used in testing for short-circuits. In this method the two small coils on the back of the E and the telephone receiver are omitted, and a laminated iron yoke is laid across the tops of the outside and middle sections to complete the middle circuit. An ammeter is connected through a series transformer in the circuit of the exciting coil, and a voltmeter is connected across the terminals. The coil to be tested is placed over the middle section of the E, and the primary voltage is raised to that specified for the coil under test. By this means a definite voltage per turn is induced in the coil which is independent of the number of

TABLE IV—TEST VOLTAGES FOR INSULATION TESTS OF ALTERNATING-CURRENT MACHINERY

	Before Coils are Placed in Machine		After Coils are Placed in Machine		Complete Machine		
Rated Terminal Voltage	Between Conductors in Series	Conductor and Cell Representing Slot	Armature Coil and Ground	Between Phases	Complete Machine to Ground	Field Coil to Ground	Complete Field to Ground
	Momentarily	One Minute	Momentarily	Momentarily	One Minute	Momentarily	One Minute
600 and less	800 V	3 000 V	2 500 V	2 500 V	2 000 V	3 000 V	1 500 V
2 500 V	800 V	6 500 V	7 000 V	7 000 V	5 000 V	3 000 V	1 500 V
6 600 V	800 V	16 500 V	17 000 V	17 000 V	13 200 V	3 000 V	1 500 V
11 000 V	1 200 V	27 500 V	28 000 V	28 000 V	22 000 V	3 000 V	1 500 V

turns in the coil under test, but bears a constant ratio to the primary voltage. Current at 133 cycles is used in order not to saturate the iron. If there is no breakdown in the coil the ammeter reads only the exciting current of the transformer, but if the coil insulation is defective a very large current results, which is indicated by the ammeter and frequently by the opening of the circuit breaker. When the core of the transformer is excited to a high value, a very pronounced humming noise is produceed. When a short-circuited coil is placed over the middle section, the magnetic flux set up by the short-circuit current opposes that in the core, so that it is almost impossible to produce any high degree of saturation. Consequently the absence of the humming noise usually indicates a defective coil.

Direct current armatures are tested for grounds and short-circuits by placing them against an alternating-current magnet of the type shown in Fig. 8, the flux from which, passing through the core, sets up an alternating e. m. f. in the windings. If there are no faults in the insulation the e. m. f's induced in each half of the winding counterbalance each other and no current flows, but a decided potential difference exists between adjacent commutator bars. A knife-blade or a sharp piece of steel is then passed around the commutator, short-circuiting in succession, those coils which have one side under the magnet. A decided spark at the point of short-circuit, indicating a potential difference between the bars, shows that the coil is in good condition. Absence of sparking indicates either a short-circuit or an open circuit. If the coil is short-circuited a local current flows, setting up a magnetic flux around the slots containing the defective coil. This can readily be detected by passing a piece of soft iron around the core, which will have a tendency to stick over the slot containing a short-circuited coil.

Certain precautions and conditions are necessary when conducting insulation tests, and in order to make their application more clear, it is customary to divide all tests of dielectric strength into two general classes, depending on the voltage used and the static capacity of the apparatus to be tested. The first class includes apparatus for which the test voltage is less than ten kilowatts, and also all apparatus of small static capacity, regardless of the voltage used. All other apparatus falls in the second class. In making tests on either class, it is highly important that the following conditions be observed:—

1—The wave-shape of the testing circuit should be as near a true sine wave as possible, and the apparatus in the testing circuit should not materially distort this wave. The reason for this lies in the fact that all measurements of current and voltage in alternating-current circuits are made in terms of "effective values," or square root of the mean square of the average values of the ordinates in a perfect sine curve, and alternating-current voltmeters, and ammeters are calibrated to measure correctly on this basis; consequently, if the wave shape is greatly distorted, a considerable error may be introduced into the measurements, since the breakdown voltage corresponds to the maximum.

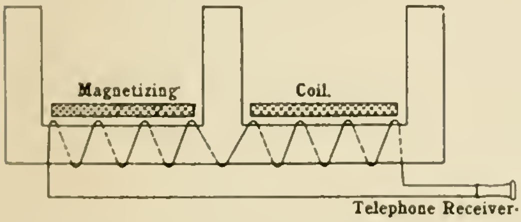

FIG. 7—TEST TRANSFORMER FOR ARMATURE COILS

2—The supply circuit should have sufficient current capacity so that the charging current which may be taken by the apparatus under test will not materially alter the wave form nor unduly affect the test voltage.

3—The circuit should be free from accidental interruptions, as these may set up momentary surges of high voltage in the circuit.

For tests coming under the second class, additional precautions are necessary. When high voltages are used, especial care should be taken that no sudden changes of any sort occur either in the primary or secondary circuit. The voltage in the primary should always be increased gradually, by the use of either a Stillwell or induction type regulator, preferably the latter, especially for high voltages, on account of the sudden though small changes in e. m. f. produced by passing from step to step of the Stillwell regulator. At the conclusion of a test it is equally, if not more important, that it be decreased gradually to a low value before opening the high-tension circuit. Under no circumstances should the high-tension circuit be opened or subjected to sudden changes of voltage with the low-tension circuit closed. In such cases, especially if the apparatus under test be of high static capacity, an arc will occur at the break, which may set up oscillating currents of high voltage in the secondary circuit, and the insulation will probably be punctured. On the other hand, if the primary be suddenly opened with the secondary closed, similar surges will be induced in the secondary.

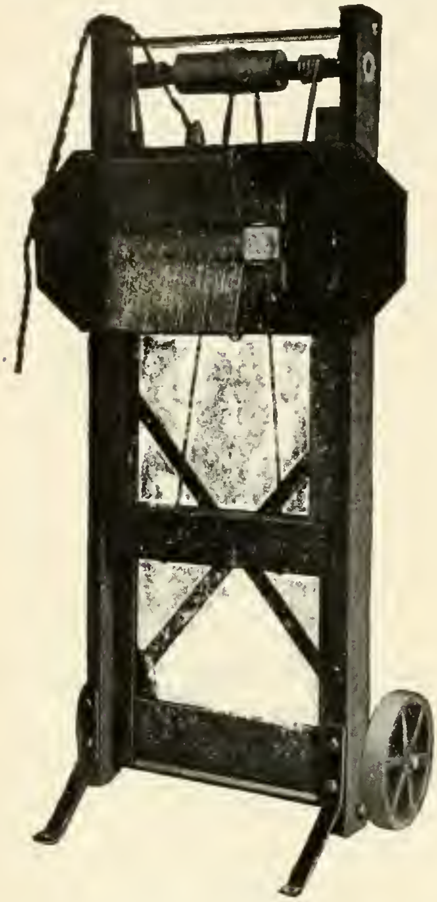

FIG. 8—TEST TRANSFORMER FOR COMPLETE DIRECT-CURRENT ARMATURES

It will thus be seen that considerable care and judgment must be used in making high-tension insulation tests in order to avoid imposing stresses on the material which are not intended when a test voltage is specified.

SWITCHBOARDS FOR ALTERNATING-CURRENT POWER STATIONS–III

C. H. SANDERSON

REMOTE MECHANICALLY CONTROLLED SWITCHBOARDS

THE many advantages to be gained from the use of the remote mechanically-controlled type of switching apparatus have been so readily recognized by those having switchboard problems to solve that their use has become very frequent. In many cases they are given preference over the self-

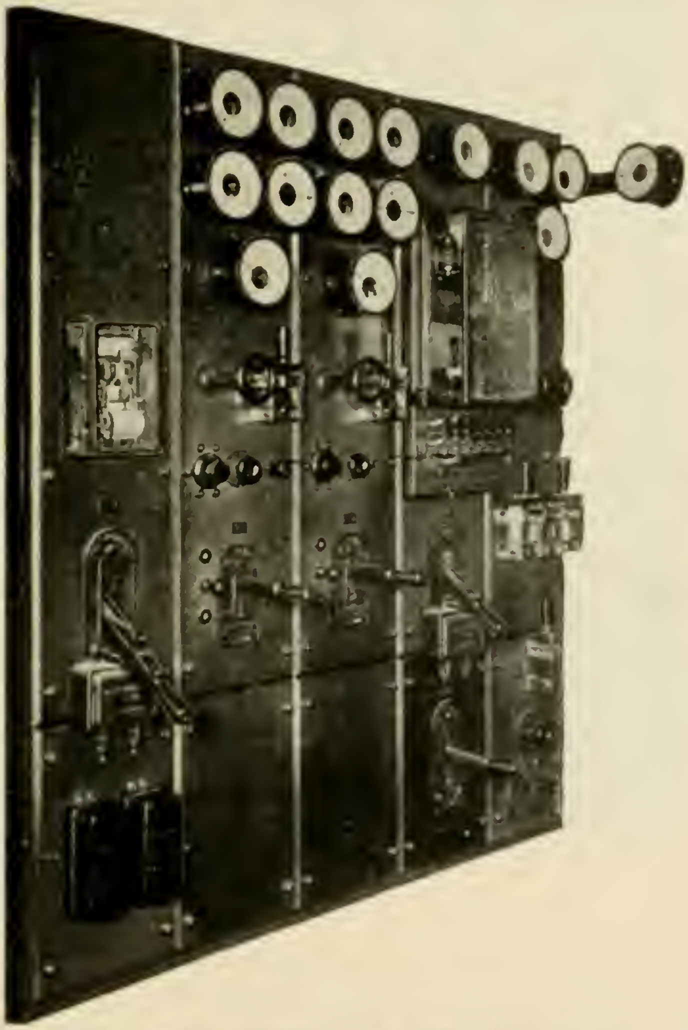

FIG. 1 –SWITCHBOARD OF MEDIUM SIZE

For controlling two exciters, two generators and one feeder as shown in Fig. 3. An alternating-current ammeter, voltmeter, indicating wattmeter, power-factor meter and field ammeter are used for each generator with watthour meter mounted on the rear of the panel. The motor panel accommodates the voltage regulator as well as the circuit breaker handle and ammeter for the motor. The exciters have individual ammeters and a common voltmeter, while the feeder is provided with a graphic indicating wattmeter and a polyphase watthour meter.

contained or the electrically-operated designs owing, either to the many desirable features secured with very little increase in cost, or to the fact that for many installations the remote mechanical control provides the same desirable operating features as may be obtained by the use of electrically-operated switching apparatus with a great decrease in cost.

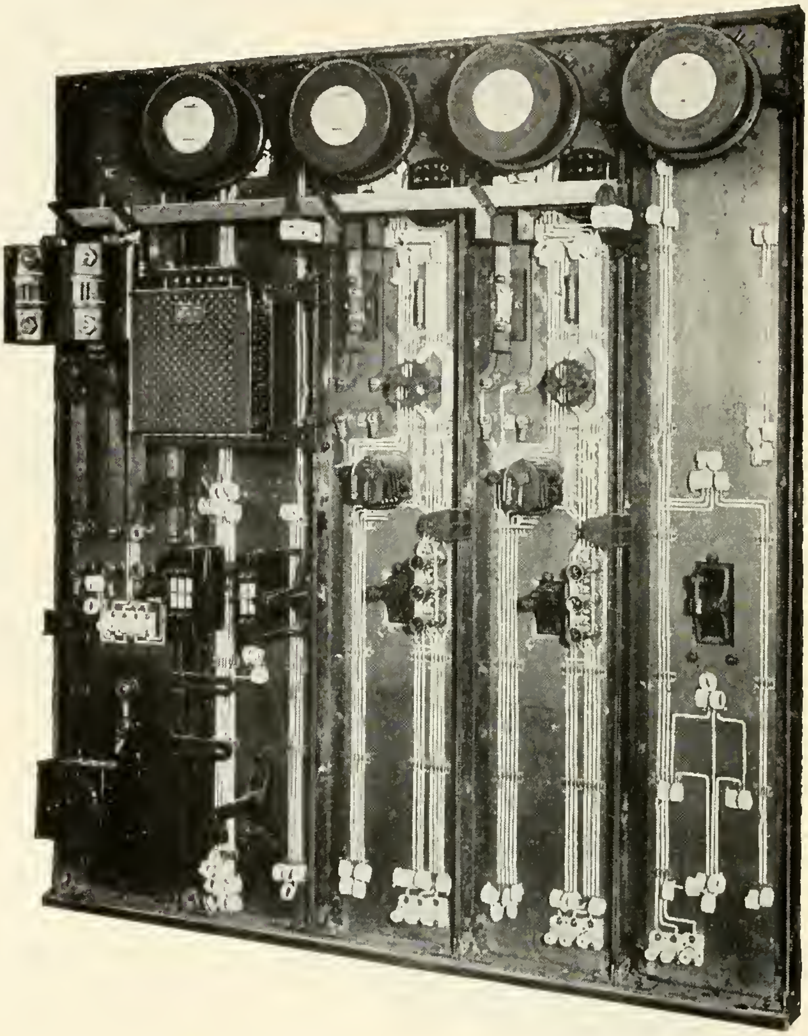

FIG. 2—REAR VIEW OF SWITCHBOARD SHOWN IN FIG. I

The watthour meters for the generator, motor and feeder circuits are mounted on short brackets at the top of the board above the direct-current field bus. The shunts of the exciter ammeter, at left of board, are mounted on a slate base. The equalizer rheostat is mounted on the sub-panel. The next panel contains the voltage regulator resistances, with condensers and brackets for circuit breaker relays mounted beneath. The two generator panels contain the field ammeter shunt, sprockets and idlers for the rheostat, controller for engine governor and ammeter receptacles.

Remote mechanical control of switching apparatus was perhaps first used in connection with high voltage carbon circuit breakers. Before the advent of the oil circuit breaker, alternating-current circuits above 600 volts were commonly opened with carbon breakers, which were usually separated by large fireproof barriers. They were mounted at the top of very high panels so as to protect the attendants against accidental contact. Remote mechanical control was thus necessitated, and the convenience and safety secured by its use soon lead to the removal of dangerous or bulky apparatus from the switchboard panels. The first oil circuit breakers were of such design and capacity as to be easily adapted to switchboard mounting. However, the demand for larger generating units and higher voltages soon necessitated circuit breakers of a size and weight suitable only for separate mounting.

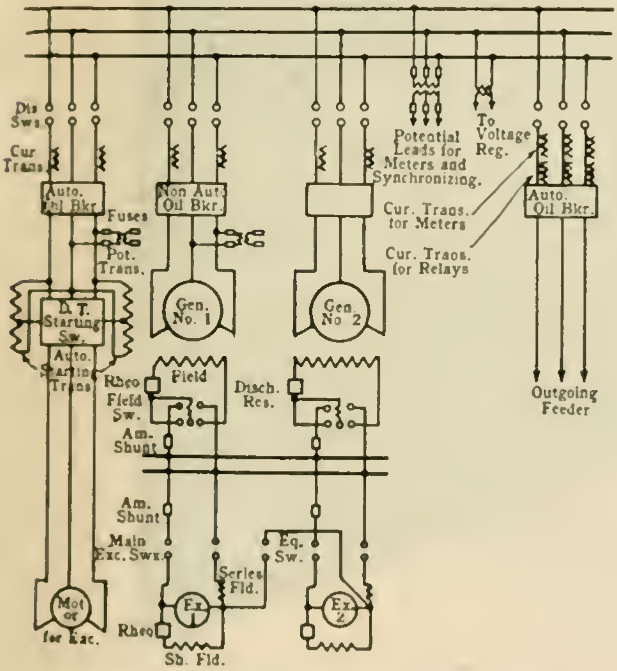

FIG. 3—DIAGRAM OF CONNECTIONS FOR SWITCHBOARD SHOWN IN FIGS. 1 AND 2

So great has been the demand for hand-operated remote controlled switching apparatus that practically all switching apparatus, regardless of size or capacity, may now be obtained suitably arranged for remote manual operation. Many of the plants of smaller capacity which could readily have used panel mounted apparatus have felt justified in incurring the small extra expense necessary to provide the remote mechanically controlled equipment. Many of the large central stations and transmission companies, while using electrically-operated equipments in their main generating and transforming stations, have adopted remote mechanical control for the same class of apparatus in their substations.

ADVANTAGES

The advantages gained by the use of remote mechanical control over that of the self-contained boards may be summarized briefly as follows:

1—All high voltages are removed from the panels, thus permitting ready inspection of the instrument and control wiring, eliminating danger of injury to attendants from contact with live parts, permitting the location of the board to much better advantage as regards the remainder of the installation because less space and less protection are required.

2—Panels are not subjected to the mechanical strains due to automatic operation or to the dead weight of the apparatus.

3—In case of marble panels their appearance is not marred by stains from creeping oil.

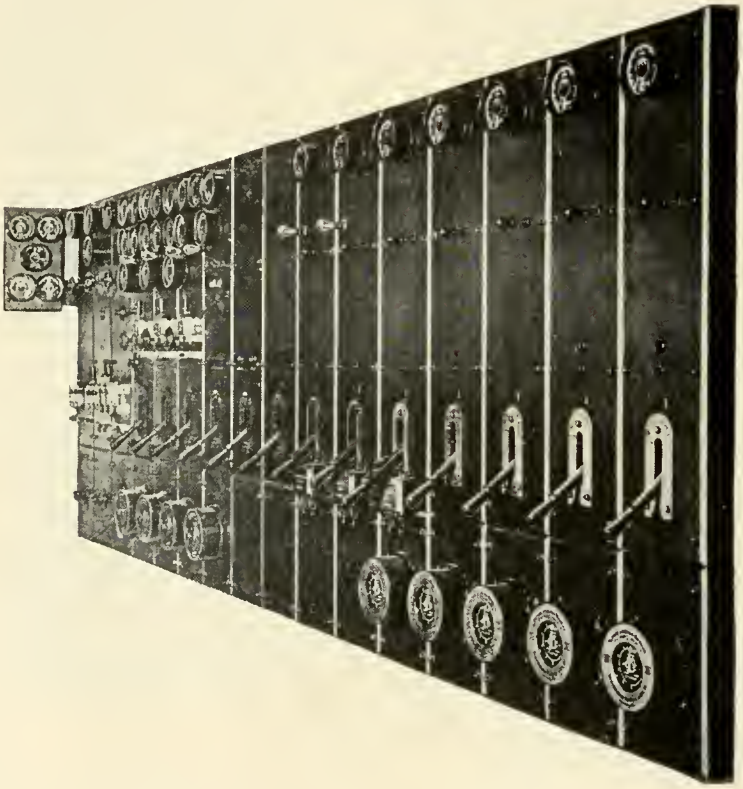

FIG. 4—LARGE REMOTE CONTROL SWITCHBOARD

For light and power distribution, controlling apparatus as shown in Fig. 6. Meters are provided with black-faced dials with white lettering.

4—Violent explosions, attendant upon the opening of heavy currents or the failure of a circuit breaker will not injure the panels and, if the circuit breakers are sufficiently spaced or are enclosed in fireproof cells, adjacent circuit breakers will not be affected.

5—The panels may be much narrower, the reduced cost thereof offsetting, to a considerable extent, the additional cost of the remote control feature. Moreover, the decrease in total length of the board may result in a very material saving in cost.

6—A more compact arrangement of the apparatus is of great assistance to the operator, approaching as it does more nearly to the compact and efficient arrangements obtained by means of control desks.

7—Much shorter main connections are made possible, and high voltages kept away from certain floors, or certain rooms by locating the remote control structure properly.

8—Where a wall is used for supporting the apparatus, the cost of the complete outfit may be reduced to very near that of the self-contained type of board, and, in some cases of very heavy capacities at low voltages, may be less in cost. Moreover, accessible arrangements of apparatus with ample spacings may easily be obtained.

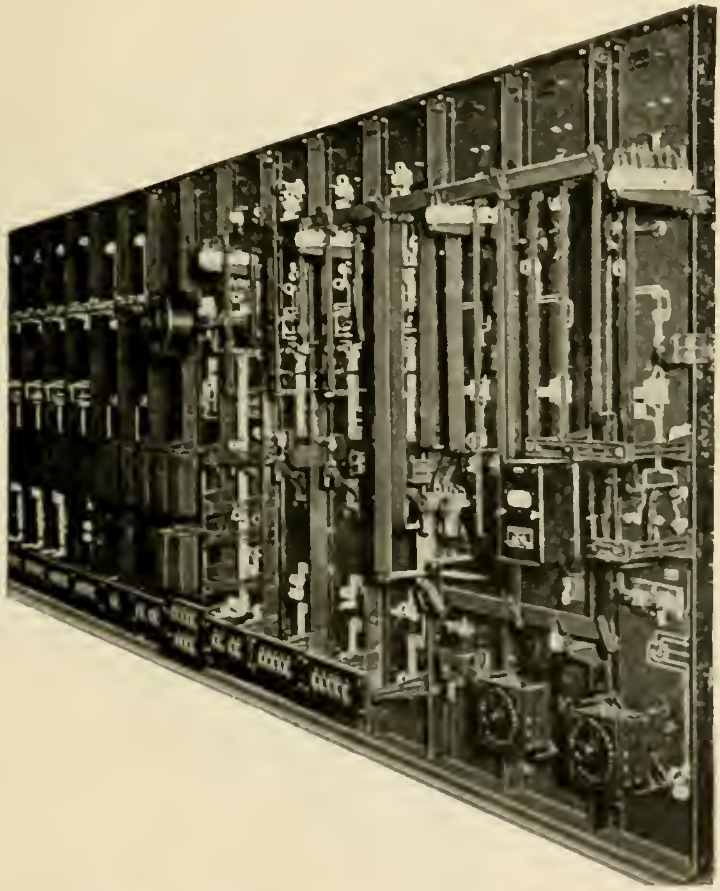

FIG. 5—REAR VIEW OF SWITCHBOARD SHOWN IN FIG. 4

The calibrating receptacles may be seen near the bottom of the alternating-current panels, with the relays just above them. On the exciter panels are shown the double exciter bus, direct-current wattmeter and equalizer rheostat.

9—Where a steel or masonry structure is used, access may be had to either side of the structure and an arrangement of this kind will satisfactorily accomodate the maximum amount of apparatus ordinarily used for either single or double-throw arrangements.

In comparison with the electrically operated board, the remote mechanically-operated board usually occupies from 5 to 50 per cent. more space although the circuit breakers and busbars for a given capacity will be practically identical. The size of the board in either case depends primarily on the number of instruments employed for each circuit, as they require more width than the control handles of the circuit breakers. The boards themselves may be identical throughout as to equipment except for the method of control of the circuit breakers and usual attendant difference in method of automatic relay tripping of the circuit breakers, the electrically-operated boards using direct current and the remote mechanical control, alternating current for this purpose.

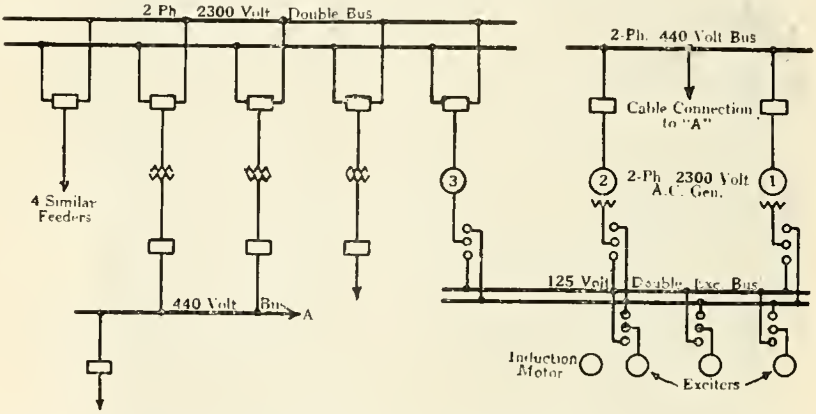

FIG. 6—SINGLE-LINE DIAGRAM OF CONNECTIONS OF SWITCHBOARD SHOWN IN FIGS. 4 AND 5

APPLICATION

The remote mechanically controlled switchboard is limited in capacity by physical, rather than electrical characteristics. As all high capacity circuit breakers may be arranged for remote mechanical control as well as electrical operation, the problem becomes one of mechancial arrangement in which it is usually very easy to meet the electrical requirements. The principal rules to be observed as regards the mechanical limitations may be stated briefly as follows:

A circuit breaker should close readily with the ordinary effort exerted by the average man using but one hand. It is impracticable to operate a circuit breaker satisfactorily at a horizontal distance much in excess of 35 feet or a vertical distance of 20 feet, with standard commercial apparatus. This distance may prove too great for satisfactory operation if more than two bell-cranks must be used or if the direction of motion must be changed, as in clearing columns or other obstructions. The inertia of the mechanism should not be sufficient to materially affect the time or power required to close the breaker. When the mechanism operates vertically, as when controlling circuit breakers on floors above or below the switchboard, the mechanism may be counterweighted to take the weight of the vertical rod off the operating handle; but, as the inertia of the mechanism is thereby increased, the application of counterweights is limited.

In view of these considerations it is recommended that this type of switchboard be confined to the use of circuit breakers of 3 000 amperes capacity or less and of 3 500 volts or less, and to stations whose capacity does not exceed 25 000 k. v. a. in high-speed turbo-generators or the equivalent in other sources of supply.

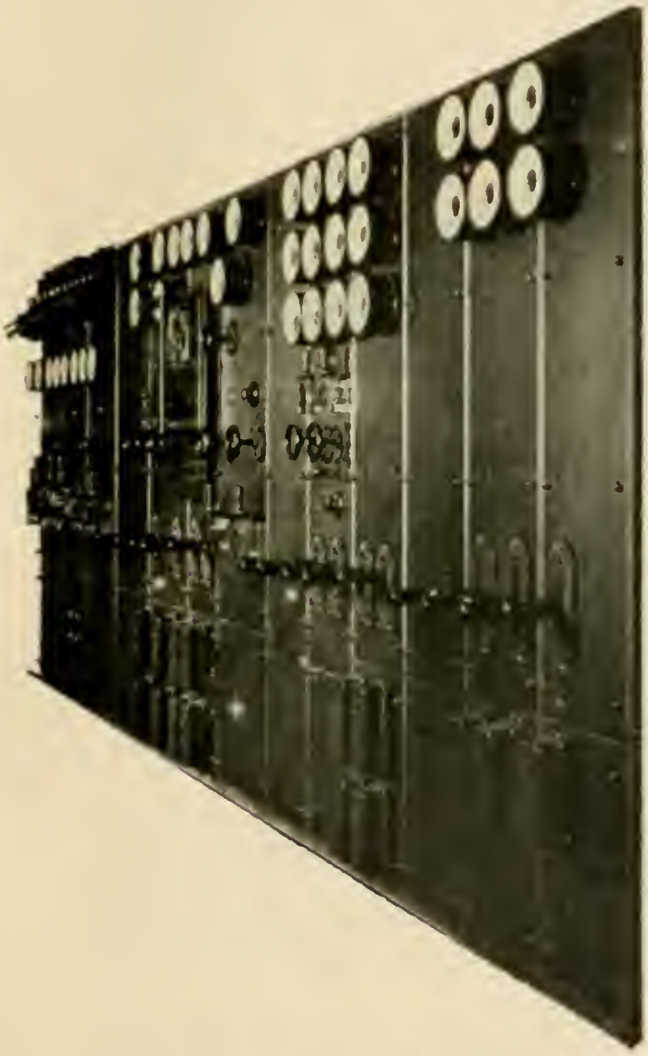

FIG. 7—LIGHTING AND POWER ALTERNATING AND DIRECT-CURRENT SWITCHBOARD FOR SMALL CITY

This is an unusually compact form of board for the apparatus it controls, as shown in the diagram, Fig. 9.

TYPES

The multi-section panel 90 inches high is almost universally used for this class of board. The installation which requires the use of remote control apparatus is of such capacity that the smaller type of board* would not be in keeping with the remainder of the equipment. For individual circuits or very small sub-stations, or when associated with small direct-current boards, however, the smaller type of panel may be employed economically and to good advantage.

Figures 1, 2 and 3 illustrate the type of board often used for a hydro-electric plant of medium size where all the power generated is taken over one feeder to the center of distribution. The exciters, which are operated in connection with a voltage regulator, are controlled from a double exciter panel containing the ammeters, a common voltmeter, main and equalizer rheostats and main switches. The second panel contains the handles for the automatic protective circuit breaker and the starting cir-

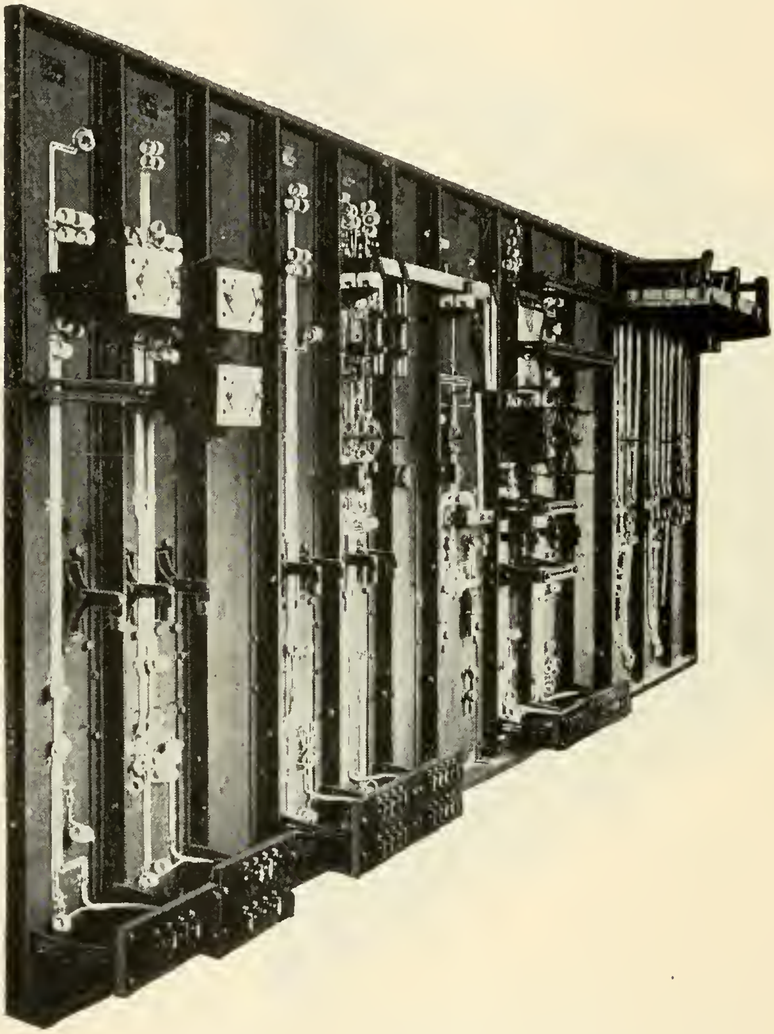

FIG. 8—REAR VIEW OF SWITCHBOARD SHOWN IN FIG. 7
The small amount of space occupied and the accessibility of all parts are clearly shown.

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* See article by author in the JOURNAL for February, 1913.

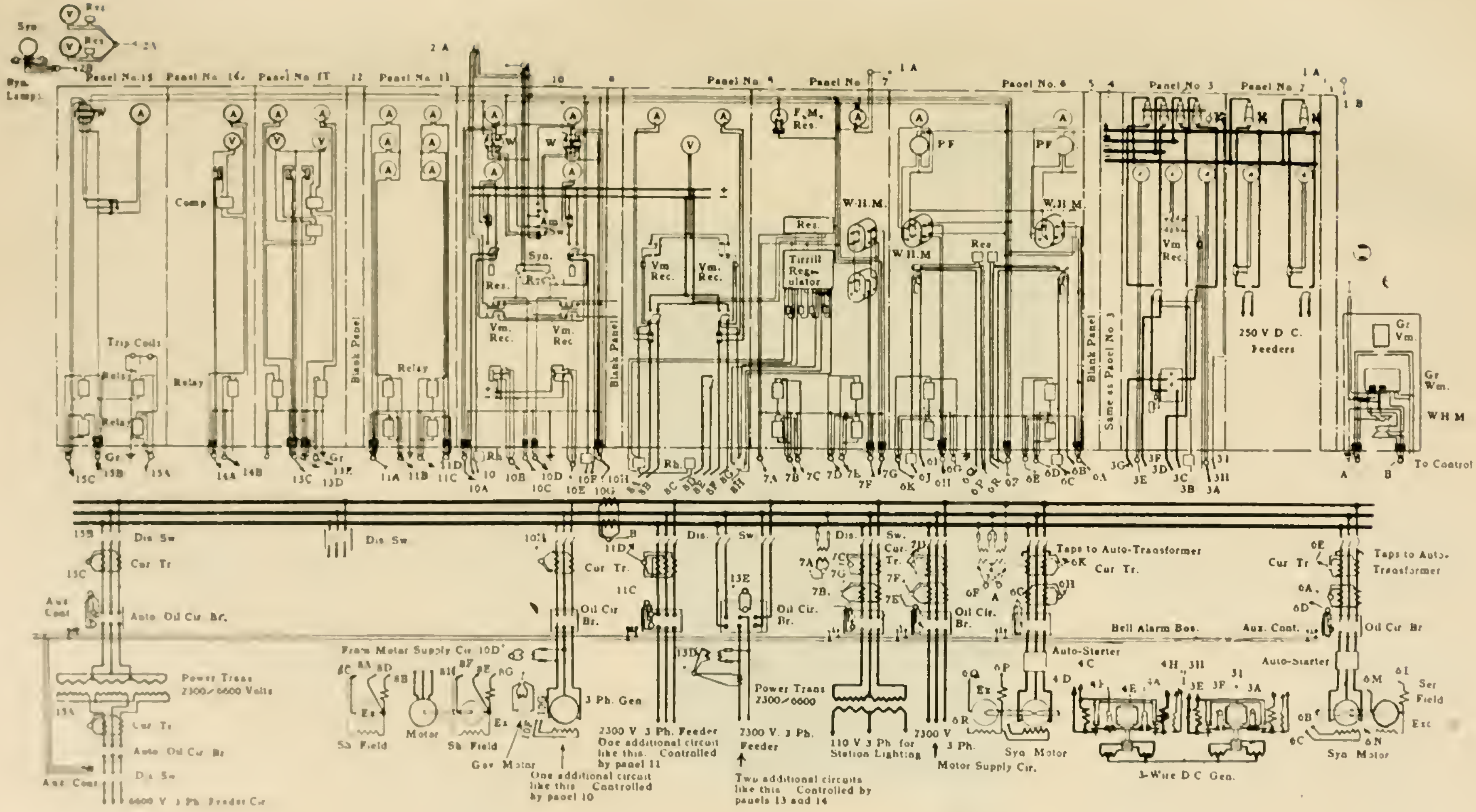

FIG. 9—COMPLETE DIAGRAM OF CONNECTIONS FOR SWITCHBOARD SHOWN IN FIGS. 7 AND 8

Two synchronous motors are controlled from one panel No. 6, 24 inches wide, with sufficient space reserved for a third. Two generators are controlled from panel No. 10, 16 inches wide with panel No. 9, reserved for two future generators. Each of the 16-inch feeder panels controls two feeders. The direct-current, three-wire generators are protected by series relays connected directly to the armature circuits.

cuit breaker, and the ammeter for the exciter motor, as well as the regulators. The two generator panels are each equipped with ammeter, voltmeter, power-factor meter, indicating wattmeter and field ammeter, and the usual switches, circuit breaker handle, plugs and receptacle with the addition of a governor speed controller. The feeder is provided with a graphic wattmeter and an automatic circuit breaker with relays, the latter usually inverse or definite time limit, but often reverse current where the station feeds into a system of power stations.

Boards for large industrial, or light and power plants, are illustrated in Figs. 4, 5 and 6. This particular equipment is mainly double throw, as illustrated in Fig. 6. The meters are all provided with black dials with white scales and lettering, which are generally considered much easier to read than the white dial. The bracket instruments, which are mounted on a swinging panel, consist of two voltmeters, a synchroscope, power-factor and frequency meter. The generator panels are each equipped with two ammeters, indicating wattmeter, voltmeter, field ammeter, watthour meter; while the feeder panels each have one ammeter with receptacles for either phase and a watthour meter. Two good methods of mounting watthour meters are illustrated in Figure 2 and 4, the former on brackets

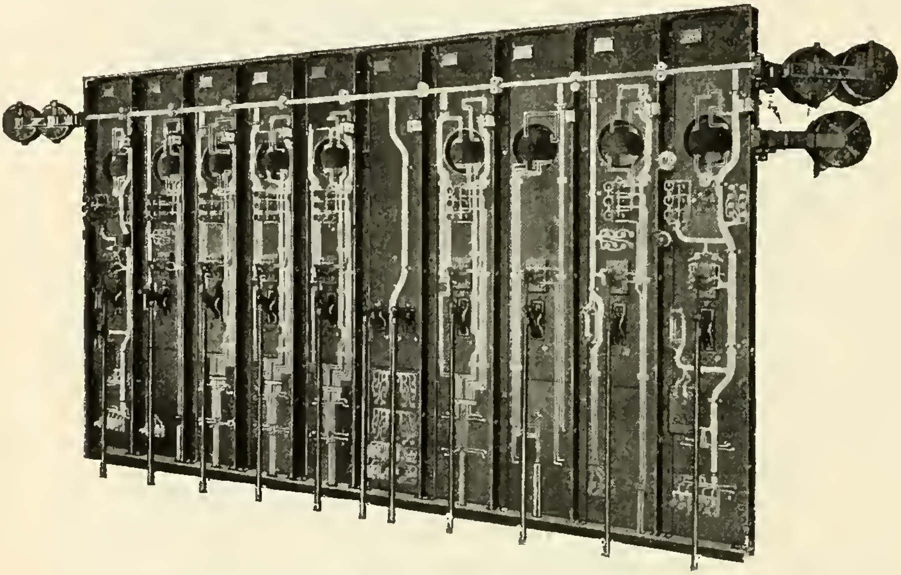

FIG. 10—REMOTE CONTROL SWITCHBOARD

Instrument busses taped in one group. Auxiliary knife-switches for instrument leads mounted above and connected to oil circuit breaker handles. Conduits for instrument wires taken through channel base of switchboard. Extreme depth of board over all, 18 inches.

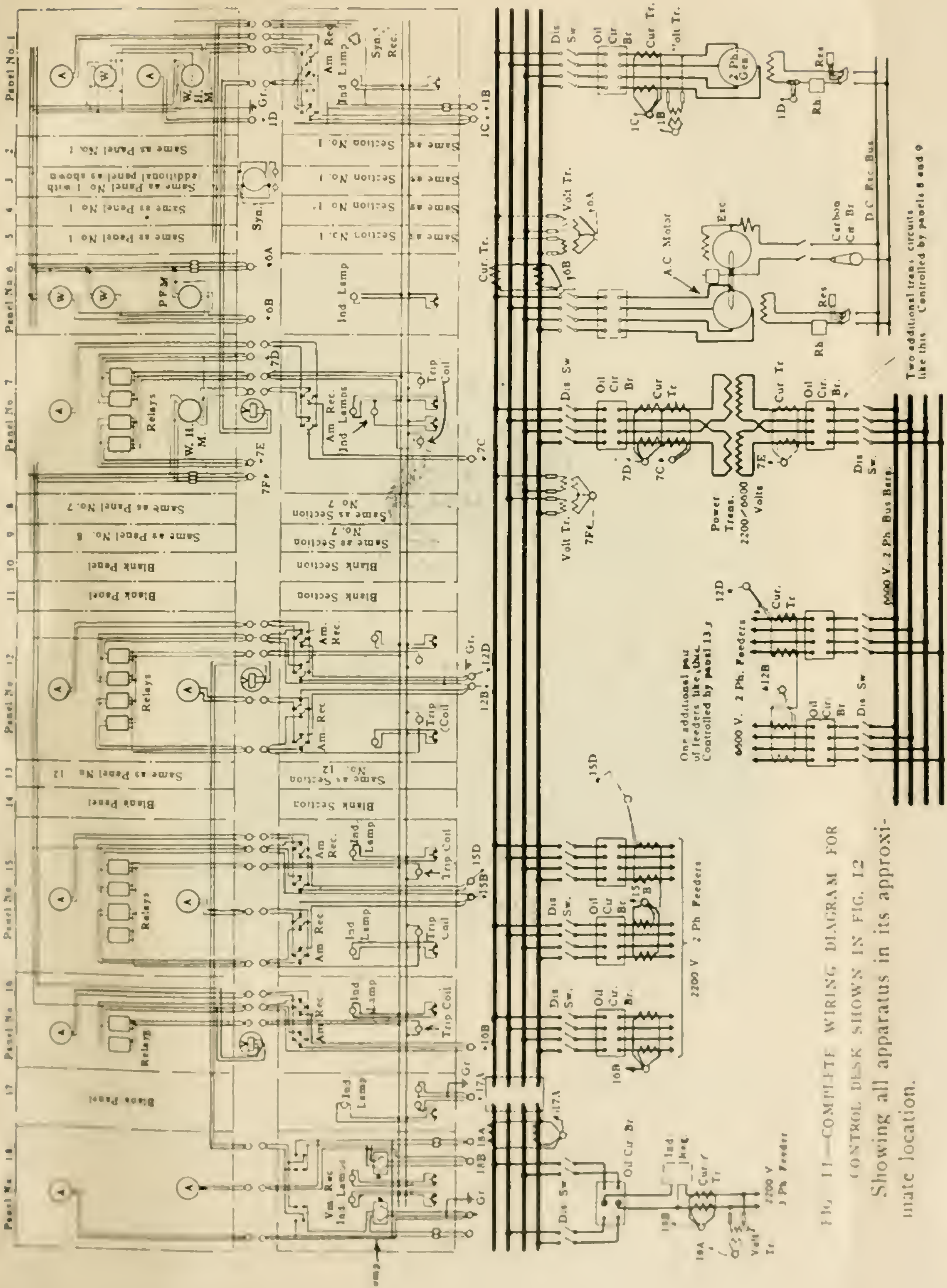

FIG. 11.—COMPLETE WIRING DIAGRAM FOR CONTROL DESK SHOWN IN FIG. 12

Showing all apparatus in its approximate location.

at the rear of the board near the top and the latter on the front on sub-sections. Fig. 5 shows the usual method of mounting relays and calibrating receptacles at the rear of the board.

The switchboard illustrated in Figs. 7, 8 and 9 is a good example of the compact, yet efficient, arrangement which this class of board affords. Sub-section mounting of relays on the front of the board is shown in Fig. 7.

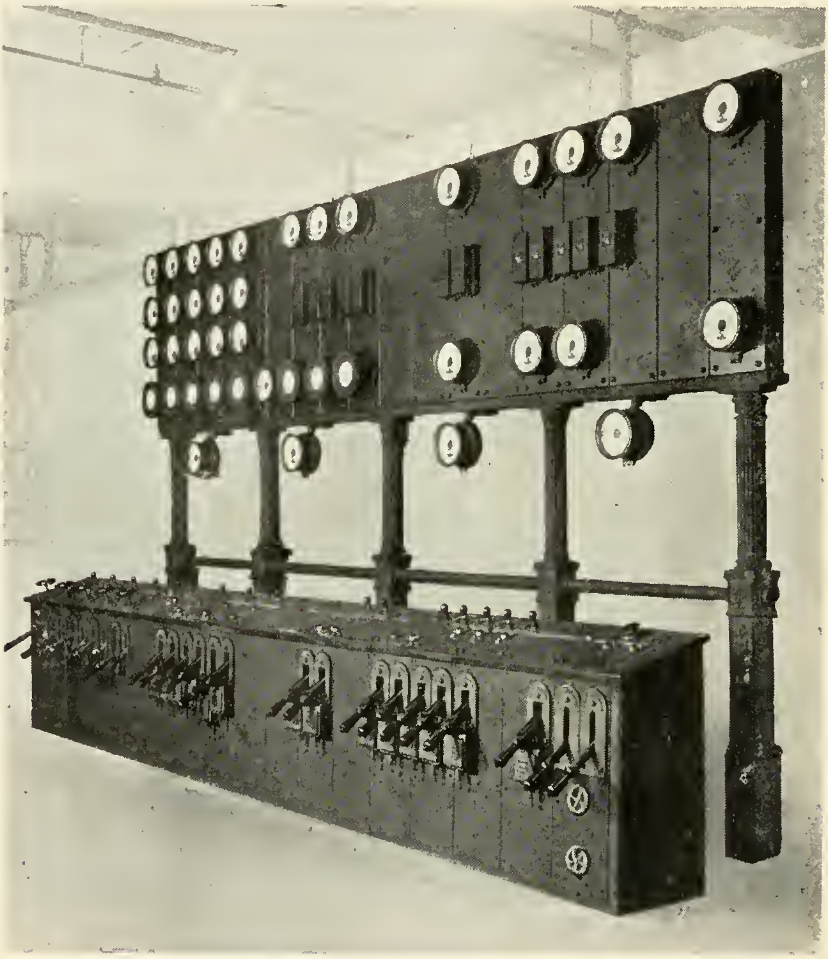

FIG. 12—CONTROL DESK AND INSTRUMENT PANELS EQUIPPED FOR REMOTE MECHANICAL CONTROL

The control desk (Figs. 11 and 12), though not yet used to any considerable extent when mechanical control is employed, is very popular for controlling electrically-operated equipments because of its many desirable features. Few of these features are lost in a properly designed desk for remote mechanical control and, as the cost does not greatly exceed that of the panel type, there is no reason why it should not be chosen for stations requiring a large control equipment.

PERSONALS

Mr. Wallace W. Briggs, assistant sales manager of the Westinghouse Electric & Mfg. Company, and located at San Francisco, has resigned to accept the position of assistant to the president of The Great Western Power Company and The Northwestern Light & Power Company, and will be located in San Francisco.

Mr. George W. Hamilton, formerly engineer on mining work in the general engineering division of the Westinghouse Electric & Mfg. Company, and a frequent contributor to the JOURNAL, has accepted the position of engineer of inspection of the Pittsburgh-Buffalo Company, with headquarters in Pittsburgh.

Mr. Charles Robbins, manager of the industrial and power department of the Westinghouse Electric & Mfg Company, has been appointed assistant sales manager. Mr. J. M. Curtin has been appointed to succeed Mr. Robbins. Mr. H. W. Cope has been appointed assistant manager of the industrial and power department.

Mr. S. F. Moore, recently foreman of turbine tests and foreman of automobile construction of The Westinghouse Machine Company, has resigned and entered the employ of the West Penn Power & Traction Company, Pittsburgh.

Mr. Parker H. Kemble, general sales manager of the Toronto Electric Light Company, has resigned to accept the position of manager of the commercial department of the Union Gas & Electric Company, of Cincinnati, Ohio.

Mr. E. T. Selig, manager of the industrial and power division of the Syracuse office of the Westinghouse Electric & Mfg. Company, has recently resigned to enter the employ of the United Gas & Electric Corporation of 40 Wall Street, New York City, as commercial engineer, and is located for the present with their New Orleans property, The Consumers' Electric Light & Power Company, New Orleans, La.

Mr. Stanley M. Smith, formerly of the engineering staff of the electrical commission, City of Montreal, has joined the selling staff of the Canadian Westinghouse Company, with headquarters in Halifax, N. S.

Mr. B. A. Appleton, a graduate of Stevens Institute, has been appointed western sales manager of the Hemming Mfg. Company, Garfield, N. J., with headquarters in suite 1654, Monadnock Block, Chicago.

Mr. Albert O'Connor, formerly of the dynamo test department of the Westinghouse Electric & Mfg. Company, has resigned to accept a position with the Electric Machinery Company of Minneapolis.

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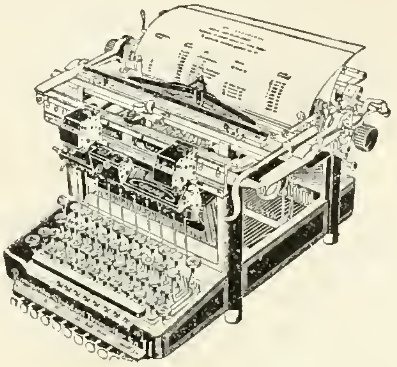

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Diesel engines have noticeably been engaging the attention of power users within recent years and engineering literature has been replete with descriptions and information regarding the development of this interesting motor. The subject, therefore, is not new, nor has been neglected but no attempt has been made previously to devote an adequate book to the Diesel engine. This the writer does in his work in a very instructive manner. The book covers the need principally of the operator, and aims not only to give him an appreciation of the value of this type of prime mover, but presents elaborately the details of design along with the fundamental principles of operation. Chapters on testing and marine work are presented. An appendix containing Lloyd's Insurance Rules is included.

E.D.D.

"Questions and Answers on the National Electrical Code"—T. S. McLaughlin. 232 pages, five illustrations. Published by the McGraw-Hill Book Company, New York City. Price, $1.00.

To those who like the question and answer style of presentation better than the definite statements, as contained in the Code, this book should prove of value. The answers allow somewhat more latitude in the discussion of the meaning of certain paragraphs. Questions which can be answered by yes or no, however, are not much of an improvement on the Code itself. Such answers are probably inserted as a means of securing completeness with reference to code sections. This book is gotten out in a small pocket size with flexible leather binding.

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THE ELECTRIC JOURNAL

Vol. X APRIL, 1913 No. 4

Improving Power Plant Efficiencies

Of the various methods of effecting power plant economies, none has attracted more attention of late years than the use of the low pressure turbine. The increase in plant capacity, with a proportionate reduction in unit cost of generating power which is thus obtainable, accounts for the extent to which they are being applied in these days when conservation and efficiency are the familiar precepts in all fields of work. Although many installations of these machines have already been made, the field has as yet been scarcely opened. This is largely due to the lack of information as to the wide possibilities, and a general discussion as to the use of such machines is, therefore, of particular value, since it indicates many other opportunities for their application hitherto unconsidered.

The article by Mr. Francis Hodgkinson, in the current issue of the Journal, entitled "The Application of Low Pressure Turbines," covers the field in a very complete way. The emphasis laid on the primary consideration, "that no steam be wasted to atmosphere," but all available be used in the most effective manner possible, is particularly appropriate. Peculiarly enough, the use of low pressure apparatus, the primary incentive to which is increased efficiency, has often been made in an inefficient manner. The classification of such installations gives the reader, in convenient form, an excellent general view of the considerations affecting such installations; in other words, exactly the perspective necessary to approach a problem of this character intelligently. The discussion of the installation in each class, besides containing valuable information as to good practice, as shown by field results, enables the prospective user to estimate closely the expense incident to making such installations and the gain in overall power cost obtainable by their use.

H. A. Rapelye.

The Humanities in Technical Education

I have been interested in reading a small collection of essays on education printed in 1761, containing, among other papers, a letter by Milton, Locke's "Essay on Education," and various papers from the *Spectator.* The immediate point of interest is the criticism, even at that early day, in many of the papers, of educational methods in general and "those licensed tyrants, the schoolmasters" in particular. There is too much Latin and too much Greek and too little English and "Merchants' Accompts." Now, after three hundred years, but mainly during the past fifty years, we have almost eliminated the Greek and the Latin and have our English and accounts multiplied a hundredfold, but we are still dissatisfied.

There is little originality but obvious truth in the observation that education has two aims; to train a man intensively for the work he expects to do, and to give him a general training in other branches of learning so that his interests outside of his work may be healthily developed. This idea was well expressed but from a different viewpoint by the *Spectator* in one of the papers included in the collection mentioned:

"The design of learning is, as I take it, either to render a man an agreeable companion to himself and teach him to support solitude with pleasure; or, if he is not born to an estate, to supply that defect and furnish him with the means of acquiring one."

Today we would change this only to combine the two functions. But our schools are far from accomplishing these aims. Too often education for companionship is absent entirely, and education for business is wide of the mark.

It is only human to value most highly the training we, ourselves, have missed. That may explain my own feeling that engineers, in common with other educated men, should obtain before they leave college a speaking acquaintance at least with the humanities and natural sciences, not because of any direct benefit in their professional work, but solely to enlarge their interests, quicken their sympathies and so prevent premature mental old age. That this feeling is shared by many practicing engineers was brought out by an incident of the past winter. Twenty or more college graduates of from ten to twenty years standing organized themselves into a class to study psychology under a professor from a local University, and showed their sustained interest, not only by attending a series of ten evening lectures, but by paying their money for them. It is true that some joined the class with the expectation that the principles of psychology could be directly applied in their daily relations with other men. While this hope was not realized to any extent—applied psychology is still a long way from being an exact science—the sentiment of the class at the close of the lectures was unanimous that the course had been of great value to them in broadening their understanding and sympathies, and of considerable indirect value in their daily practical work. This incident is simply an illustration of the value placed by experienced engineers on a subject seldom associated with engineering. If psychology and kindred branches of learning are desired by practical engineers, they are certainly worthy of consideration for the undergraduate.

It must be granted that if the cultural studies are to be increased, the technical must be diminished. I believe that a part of the present technical instruction can be omitted with profit to all concerned, and so make a place for more of the work usually associated with a classical course.

Engineering education may be divided broadly into three parts: those studies that give the required mental attitude and training for work that must square with rigid and exact natural laws; those studies more closely allied with practical work that teach the general methods of conducting engineering investigations and provide tools for the work; and, finally, the actual practical experience in the work itself. The first two classes are properly the work of the schools; the third class, while occupying part of the school time and a large part of the senior year of many courses, can only be carried on with any degree of satisfaction outside of the schools and in the practical commercial world.

It is difficult to distinguish between studies of the first and second classes mentioned, since most branches, if in either class, partake of the nature of both. Fortunately, it is not necessary, since both come properly within the province of the school. On the other hand, it is easy to separate the third class from the other two, which is the important distinction. These distinctions can be illustrated by considering the question of instruction in design methods. So many books on detailed design calculations have been published for engineering students that the subject is surely considered, by the authors at least, a proper one for instructional purposes. Most designing is partly an art and partly a science, the proportions depending as much on the nature of the designer as on the nature of the structure to be designed. Proficiency in the art can only come from practice and experience, and complete designs involving the art as well as the science can have very little value from a pedagogic standpoint. The necessarily brief time available, the lack of perspective, in both teachers and students, that only experience can give, and the impossibility of checking by construction and test the designs worked out, all help to bring this about. The designing of complete machines and structures is then a subject the colleges can profitably leave to the school of experience. But there are fundamental principles at the bottom of most designing methods which afford excellent material for instruction. In electrical machinery design, for example, there is enough material in the study of the two fundamental elements of machines, the electric and magnetic circuits, to bring out all the important principles and methods used in actual designing. If these fundamentals are understood, polyphase armature windings need not be mysteries to be taken on faith; the actual results from many correct and incorrect connections and slot arrangements may be quantitatively plotted; the effect of the shape of pole face and number of slots per pole may be independently investigated by the student; magnetic leakages may be calculated from fundamental considerations of potentials and reluctances and need not be guessed at as a "leakage factor." And if the fundamentals are thoroughly studied, the methods of investigation used become tools in the permanent possession of the student that may be applied to the solution of a wide range of practical design problems, a result far more important than the making of a complete and detailed design, the material for the greater part of which the student has necessarily taken on faith.

In striving after the practical, our technical schools have undertaken work that can better be left to apprenticeship courses and other commercial organizations. They have omitted cultural studies as a consequence, resulting in a personal limitation the student rarely removes.

F. D. NEWBURY.

THE APPLICATION OF LOW PRESSURE TURBINES

FRANCIS HODGKINSON

INASMUCH as a low pressure turbine works with substantially half the heat drop of a high pressure condensing turbine, its construction is more simple and there are fewer turbine elements. As the volumes of steam which pass through the turbine are comparatively greater, larger blade passages are permitted, all of which conduces to the simplicity and ruggedness of the turbine and facility of design. In low pressure turbine applications, therefore, the skill of the engineer is frequenty called upon more in connection with the method of applying the turbine than in its actual design. It is the object of this article to set forth some of the considerations which must be considered in making such applications.

The following may be cited as questions which arise when such an installation is contemplated. Is there enough steam for the low pressure turbine, and has its quantity been properly estimated? Although for preliminary purposes a sufficiently accurate guess of the available quantity of steam may be made, the use of indicator cards from the high pressure machines is advisable.*

Steam meters furnish an alternative method of arriving at the desired figures, although the preferable procedure is a complete test of the boiler plant itself. It is advisable to make a deduction of ten percent from the apparently available amount of steam to allow for the moisture in the exhaust from the engines.

A second typical question is that of the governing of the turbine. Should this be accomplished by the direct application of a centrifugal device to the turbine, or should arrangements be made to tie together electrically the generators driven by the turbine and by the reciprocator furnishing the exhaust steam? If a governor is used, acting directly on the turbine, should it control the inlet to the turbine alone, or should it be connected to a valve in the low pressure line permitting a portion of this steam to pass directly to the condenser and thus lowering the back pressure on the reciprocating engines whenever possible, due to low load on the turbine? Should the turbine be complicated and its overall efficiency somewhat reduced by the addition of a high pressure element so that it will operate with passable efficiency on steam direct from the boilers? Finally, should the low pressure turbine be installed at all? Does the condition of the reciprocating engines warrant their perpetuation, or would the best results be obtained by the installation of complete expansion turbines? This condition exists in many plants where low pressure installations are suggested.

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*The analysis of these cards may be made in a most satisfactory manner by the method described before the A.S.M.E. at Cleveland in May, 1912, by Mr. Paul Clayton.

CLASSIFICATION

Low pressure turbine installations may be more or less readily classified, and the various types are here enumerated for convenience. A more detailed discussion of each appears in the succeeding pages.

Case A—A low pressure turbine taking steam from the exhaust of a reciprocating engine, the generators of each being connected to the same bus-bars and no governing device used.

Case B—A turbine or a number of turbines and engines connected similarly to *Case A*.

Case C—A low pressure turbine operating in conjunction with one or more engines as in *Cases A* or *B*, except that the turbine and engine-driven generators are of different electrical characteristics. A direct-current street railway generating plant, with alternating-current distribution to distant substations, is a good example of this case, the turbine and engine-driven generators being tied together by rotary converters or motor-generator sets. Another expedient by which the use of a governor could be eliminated is the connection of the turbine-driven alternator to bus-bars upon which floats a synchronous motor belted or direct-connected to the reciprocating machine.

Case D—A low pressure turbine operating on the steam exhausted by a number of engines, pumps or other apparatus, without any relation between the electrical output from the turbine and the amount of steam available. In such a case a governor controlling the admission valve of the turbine is obviously necessary, as is a relief valve, permitting any excess of low pressure steam to pass to the atmosphere.

Case E—A low pressure turbine operating on the exhaust from engines which are carrying an independent load, as in *Case D*. The turbine governor, however, controls a valve which connects the reciprocating engines with the condenser, imposing on them only enough back pressure to enable the turbine to carry its load. The engines thus have the benefit of some vacuum whenever the load on the turbine is light enough to require less than atmospheric inlet pressure.

Case F—A low pressure turbine operating in conjunction with an engine driving a mill or a system of shafting, the output of the turbine being used for motors, lights, etc. Any excess of current generated over the electrical demand may be returned to the shafting by using a synchronous motor, coupled or belted to the line shaft, and thus acting as a balance to proportion the load between the two machines so that the best economy may be obtained.

Case G—A low pressure turbine receiving steam from an intermittently operating engine such as a hoisting engine or a rolling mill drive. If the intervals in the steam supply are not too great, a regenerator may be employed, absorbing the excess supply of steam at one time to give it up again to the turbine when the latter demands an amount exceeding that passing from the engine.

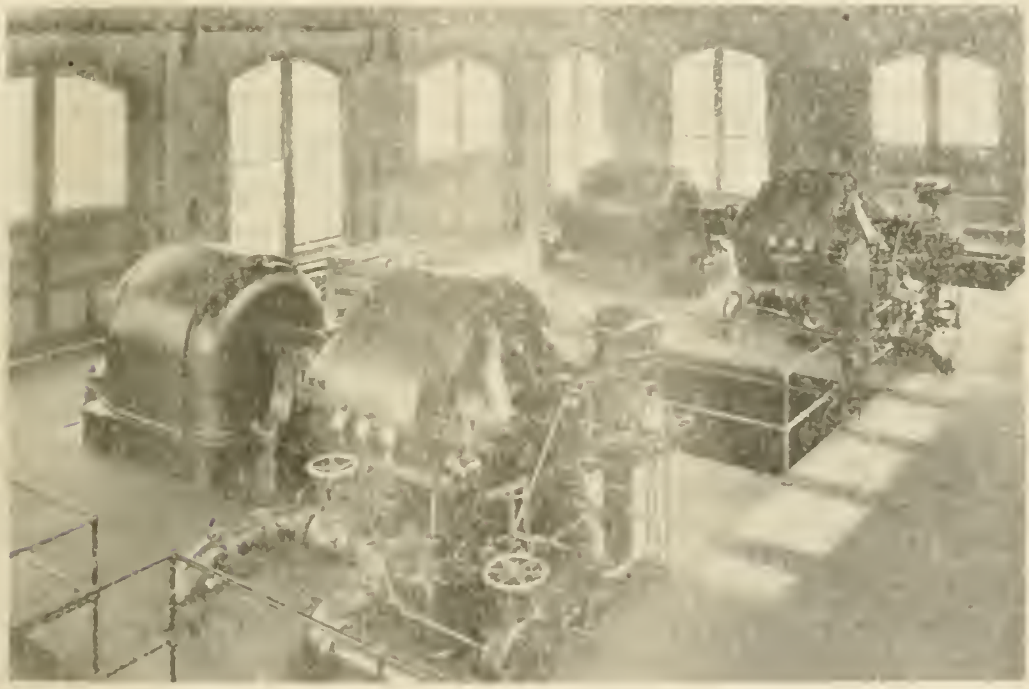

FIG. 1—INSTALLATION OF LOW PRESSURE TURBINES
An example of Case B

Case H—Practically all turbines equipped with governors have a valve which will admit sufficient live steam to carry the normal load should the low pressure supply fail. Such an arrangement does not, however, give high efficiency on high pressure steam since its expansive energy is wasted in throttling and only a small amount is recovered from the resultant superheat. *Case H*, therefore, provides what is termed a mixed pressure turbine which, in addition to the low pressure section, is equipped with elements enabling it to expand steam from boiler pressure to that of the condenser. Such a turbine is, of course, so constructed that all the available low pressure steam enters it at the proper point. A mixed pressure turbine is, therefore, used where it gives better overall efficiency, although it has a poorer economy on low pressure steam alone due to the dead load of the idle high pressure element. The relative proportion of the high and low pressure elements will be determined by the amounts of steam of each class to be handled and the continuity with which they are supplied. Such a turbine must, of course, be equipped with a governor.

GENERAL

The primary general consideration in any low pressure installation is to insure on the one hand that the turbine will receive sufficient steam to enable it to meet all demands for load; and, on the other, that all the available exhaust steam is utilized either in the turbine or in some manner even more efficient about the plant. The installation should, therefore, be so arranged as to absolutely preclude the possibility of exhaust steam escaping to the atmosphere.

In this connection it is pertinent to state that, while the low pressure turbine is an exceedingly efficient machine mechanically and affords an economical means of using a by-product often wasted, its absolute thermal efficiency is only approximately ten percent. Exhaust steam condensed in a feed water heater, on the other hand, shows a return of approximately eighty percent, so that such a heater should have first consideration in any low pressure installation. In general, the amount of exhaust steam required for heating the feed water is about one-sixth of the total amount. In several cases previously cited, the pressure in the receiver from which the turbine draws its steam, is subject to variation. It rises with the load, and below full-load is apt to be slightly less than atmospheric. If the feed water heater were connected with this receiver, the temperature would be low when the receiver pressure was low. In such a case, a good arrangement would be too take the exhaust from all the plant auxiliaries and collect it into a single main leading to the heater. Then any steam not condensed in the heater would pass from it through a constant pressure valve such as shown in Fig. 2, and thence into the receiver from which the low pressure turbine draws its steam. Thus the feed water passing to the boiler feed pumps would be at 212 degrees F., an ideal condition and one readily obtained provided the amount of exhaust steam from the auxiliaries is always sufficient to produce the desired heating effect. Obviously, the heater must be protected by a relief valve in order that the pressure may not reach an unduly high value. This valve should be preferably a back pressure valve of first-class make, absolutely tight and capable of being loaded to about 10 lbs. above the maximum receiver pressure. The auxiliaries, of course, must be capable of operating against the pressure corresponding to the highest receiver pressure.

It is advisable in all low pressure turbine work that particular care be taken to remove all moisture and foreign matter from the steam before it enters the turbine. Wet steam will do no harm of itself, but has a bad effect on the economy of the turbine since its presence acts as a brake. The oil present in the exhaust from the reciprocating engines has been found in several instances choking the steam passages through the blades. Pure, clean oil of itself would pass through a turbine without accumulating, but in cases where the boilers sometimes foam, discharging sulphates, carbonates or other solid matter with the steam, this mixes with the oil to form a gummy deposit on the blades which is exceedingly difficult to remove.

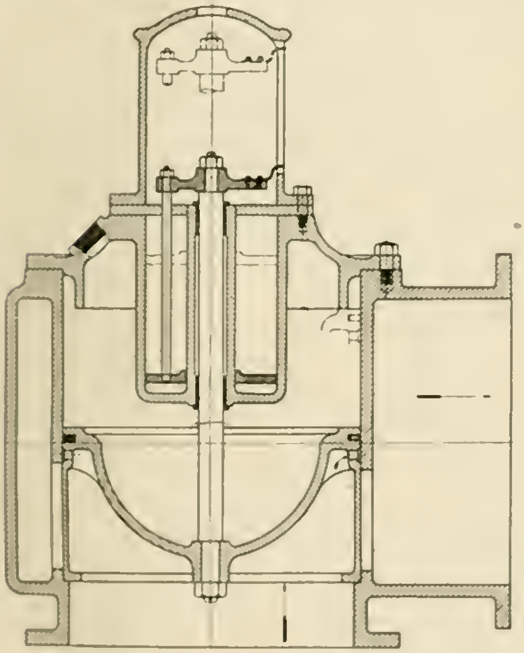

FIG. 2—CONSTANT PRESSURE VALVE

Any of the turbines mentioned above, whether equipped with a governor regulating the admission of steam or not, should be provided with a speed-limiting governor or automatic throttle, which will prevent the machine from running away should other means of control fail. In speaking of turbines operating without a governor, the reference is, therefore, to a device for regulating the machine within close limits of speed, and while for reasons which will be shown hereafter, the most economical performance of the turbine will generally not be obtained when it is under such control, it may be desirable to equip the turbine with such a governor so that it could be operated as an independent unit in the case of a failure of the reciprocating apparatus. When operating normally, however, the governor may be adjusted by means of a speed-changing screw so that the governor valve will remain wide open at all times, and thus all the exhaust steam will be used by the turbine and none wasted to the atmosphere. In this event, the governor would, of course, control the turbine should the speed rise materially above the normal. A governor might also be provided, controlling the admission of live steam alone, thus saving the expense of a low pressure valve and permitting proper operation of the turbine with live steam when there was no low pressure steam available, a condition which might arise due to accident to the machine from which the exhaust was passing to the turbine.

It will be understood that in any of the foregoing cases the application may be made with direct as well as alternating-current generators, the only difference being that with direct-current generators the speed will rise slightly as the proportion of load taken by the low pressure turbine rises, or as the quantity of exhaust steam increases, this rise in speed being in accordance with the voltage characteristics of the generator. For the same reason it is possible to vary the speed of the turbine slightly by manual adjustment of the field rheostat. Obviously when the turbine generator is an alternator and operates in multiple with others driven by reciprocating engines, the starting of the unit is extremely simple. The process of synchronizing need not be resorted to, as it is customary, before starting the reciprocator and turbine, to establish the field charge. Therefore, when the reciprocator is started, the low pressure turbine will come up to speed in synchronism.

Another consideration that should be borne in mind is that low pressure turbines may be installed in conjunction with engines previously operated condensing, as well as those performing non-condensing service. The gain will, of course, be somewhat less, but roughly speaking, the use of thirty percent more steam than was required by the reciprocators operating condensing, will produce 75 percent more power when these are converted to non-condensing operation and their exhaust passed through a low pressure turbine of proper proportions. Condensing engines so converted, do not necessarily suffer reduction of capacity because of the back pressure to which they are subjected. On the contrary, the capacity of such an engine may be increased if it is a high expansion ratio engine, providing the generator will stand being increased in rating and providing the high pressure cylinder of the engine has enough vol-time to pass the required amount of steam without taking steam for the entire length of its stroke. In many cases it is well worth while to make provision for this increased capacity by such modifications of the generator as increased air circulation, etc. The reason for this increase in capacity is that in laying out the altered indicator card of the engine for a higher back pressure, the cut-off in the high pressure cylinder will have to be moved along to a point late enough so that expansion in the low pressure cylinder will not result in looping or, in other words, to a final pressure at the opening of the low pressure cylinder exhaust valve, lower than that of the line to the turbine. Under these conditions it will be found that the top portion of the card will be increased in area or fattened, adding more area to the total than is taken from the lower portion by raising the back pressure to that of the atmosphere or thereabouts. There will sometimes be found compound engines operating condensing in which release in the low pressure cylinder takes place at a relatively high pressure, possibly close to atmospheric. If a low pressure turbine were applied in this case with a view of obtaining increased overall efficiency, the engine capacity, instead of being increased, will be decreased, since the possibility of adding area to the upper part of the card does not exist.

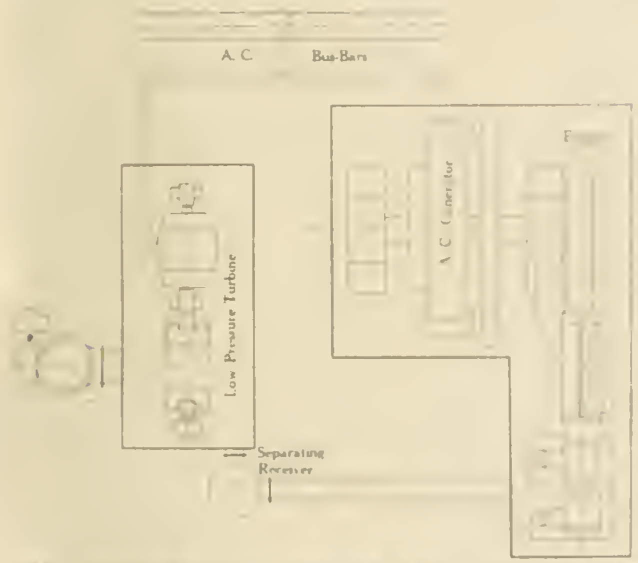

FIG. 3—DIAGRAM OF ENGINE AND LOW PRESSURE TURBINE CONNECTED ACCORDING TO CASE "A"

Having shown the classes into which low pressure turbine installations naturally divide, and the general considerations which affect all such installations, the remaining pages will be devoted to a more detailed discussion of the application of such machines in the various classes indicated. It will be well to recall that the primary function of a low pressure turbine installation is to produce the maximum obtainable amount of power per unit of steam generated in the boilers, and that, therefore, every care should be taken that all steam so generated will be used in the most efficient manner possible.

CASE A

This is the simplest form of low pressure turbine installation, and is shown diagramatically in Fig. 3. From the diagram it will be seen that the turbine and reciprocating engine are tied together electrically and that no governor is indicated on the turbine. If the turbine drives an alternating-current generator, it will take its share of the load in proportion to the steam available. As it tends to forge ahead of the reciprocating engine generator, it will take more of the load, thus removing load from the reciprocator and reducing the supply of exhaust steam. The self-regulation is, therefore, perfect, the governor on the reciprocating engine controlling the amount of steam to the complete system. In case the turbine and reciprocator drive direct-current generators, as the turbine tends to take more load, the speed increases slightly, and with that the voltage and the system is again self-regulated.

There is a great inherent advantage in this application of a low pressure turbine which is directly due to the variable pressure existing in the receiver or pipe line between the engine and turbine. The absolute inlet pressure of a turbine varies directly with the amount of steam passing through it. Reciprocating engines designed for either condensing or non-condensing operation generally have such a valve setting as will normally provide a considerable pressure at the point of release of the low pressure cylinder so that when the load on the engine is light, the indicator card will not loop. Such an engine, therefore, when carrying full load does not completely expand the steam within the cylinder, and this is a serious source of loss in engines designed for operation on variable load. In this case when the low pressure turbine is applied, there is no necessity for this provision of pressure at the point of release. The valve setting may be made such that with normal load, expansion within the cylinder will carry the steam to approximately atmospheric pressure, or perhaps a half pound above this, in order to pass the steam readily through the ports. The low pressure turbine blading proportions will then be made such that the inlet pressure will be equal to atmosphere when passing the quantity of saturated steam exhausted by the engine when operating at normal load. If, now, the quantity of steam taken by the reciprocating engine is reduced say to one-half, the absolute inlet pressure of the turbine will similarly be one-half. The high pressure cylinder of the reciprocator will have its cutoff reduced approximately one-half and the expansion of steam within the low pressure cylinder will continue to a point corresponding approximately to the turbine inlet pressure. There will be no looping of the card and the expansion of the steam through the cycle will be effected in an ideal manner.

The proportion of load carried by the engine and the turbine varies with the quantity of steam. The greater the total load the greater the proportion taken by the turbine, due of course, to the variable receiver pressure. The higher this becomes the greater is the heat range through which the turbine works. In turbine applications of this kind, as in several of those that follow, asynchronous or induction type generators may be employed. These have the advantage of requiring no field adjustment.

CASE B

This case is similar to *Case A*, except that the larger the number of units involved, the greater is the number of combinations possible. A plant of this type is shown in Fig. 1. The desirable arrangement in installing a number of low pressure turbines is to equip each with its own condenser. This conduces to flexibility of the plant over that obtainable where one large condenser is installed to serve all the turbines, as it materially reduces the probability of a shut-down due to condenser failure. In plants of any considerable size, the desirable method of applying low pressure turbines is to install one for each engine, the plant becoming a multiple of *Case A* and each engine-turbine unit being comparable to a simple engine which has been compounded by the addition of a low pressure cylinder, the only difference being that the two portions are tied electrically instead of mechanically. The regulation of the system is exactly the same as that of *Case A*, except that the capacity of the low pressure turbine may be too small to handle the amount of steam exhausted from the number of engines that are in operation. Part of the exhaust steam would, therefore, escape to the atmosphere and be wasted. A low pressure turbine is generally designed so that the maximum load on the generator will be reached when the inlet pressure on the turbine is about 20 or 21 lbs per sq in. absolute, and it is, therefore, customary to set the relief valve on the low pressure pipe line to open at about this pressure. The same consideration affects the variable back pressure on the engines in this case as in *Case A*.

In installations of these two classes care should be exercised that no air may leak into the system when the receiver pressure is below that of the atmosphere, since such air will seriously affect the performance of the condenser, the vacuum will be reduced, and the full possibility of gain from the use of the turbines will not be realized. Obviously, the greater the number of engines and the longer or larger the exhaust pipe system, the greater attention must be paid to this point. It is frequently necessary to provide special double packing rings on the rods of all the engines, such packing being so arranged that steam at a pressure slightly greater than the atmosphere is admitted between the two rings and any leak into steam spaces will, therefore, be of steam rather than of air.

In some *Case A* and *B* plants there are found additional reciprocating engines and other steam using machines carrying loads having no possible relation to the electrical load, such as air compressors and pumps. The steam from such sources is, however, generally insufficient to drive the turbine except during some abnormal condition of infrequent occurrence, such as a small electrical load occurring at the same time with a high pump and compressor load. Where this factor is involved, it would be advisable to equip the turbine with a governor, setting the speed adjusting screw so that the turbine would regulate at about six percent above normal speed. Operation under normal conditions, therefore, would take place as if no governor were applied, but as soon as the over-supply of steam occurred, the governor would exercise control over the turbine. In making this provision, it would, of course, be necessary to keep the live steam valve to the turbine closed, except when it was desired to operate on steam direct from the boilers.

In the operation of such a plant, provision should be made for turning over each additional engine which is put on to load for a few revolutions, exhausting to the atmosphere, in order to completely expel from it the air which has collected in the cylinders and receiver while it was at rest. Otherwise this air discharged into the exhaust system and passing to the condenser is very apt to cause a loss of vacuum, and consequently to interfere with the operation of the entire station.

CASE C

In two classes of installation just discussed the generators of the low pressure turbines and reciprocating engines were all of the same electrical characteristics. In *Case C*, the generators driven by the reciprocating apparatus may be either direct or alternating current and the generators driven by the low pressure turbine different from all or some of them. An electrical railway power house is often of this type, the direct-current machines supplying the local feeders and the alternating current derived from existing engines or to be derived from the turbine distributing to distant substations. If the low pressure turbine in this plant were equipped with a governor arranged to meet only the demands for alternating current, steam would be wasted when the load became light and the installation would be unsatisfactory for that reason. There is a further objection that to meet the demands of certain alternating-current loads occurring at times when the direct-current load was light, it might be necessary to install some high pressure alternating-current apparatus or to furnish the low pressure turbine with live steam which would again be uneconomical operation. A convenient and satisfactory solution is afforded by tying the alternating and direct current systems together by means of a rotary converter or motor-generator set, as shown diagrammatically in Fig. 4. This will insure the use of all the steam in the most economical manner possible. Any lack of balance between the electrical loads will be taken care of by the converter, the load on the turbine and engines being divided for best economy irrespective of the division in the total output of the station. Such a plant might possibly be undesirable where lighting service is involved, due to the voltage variation in swinging over from full load alternating-direct current operation to full load direct

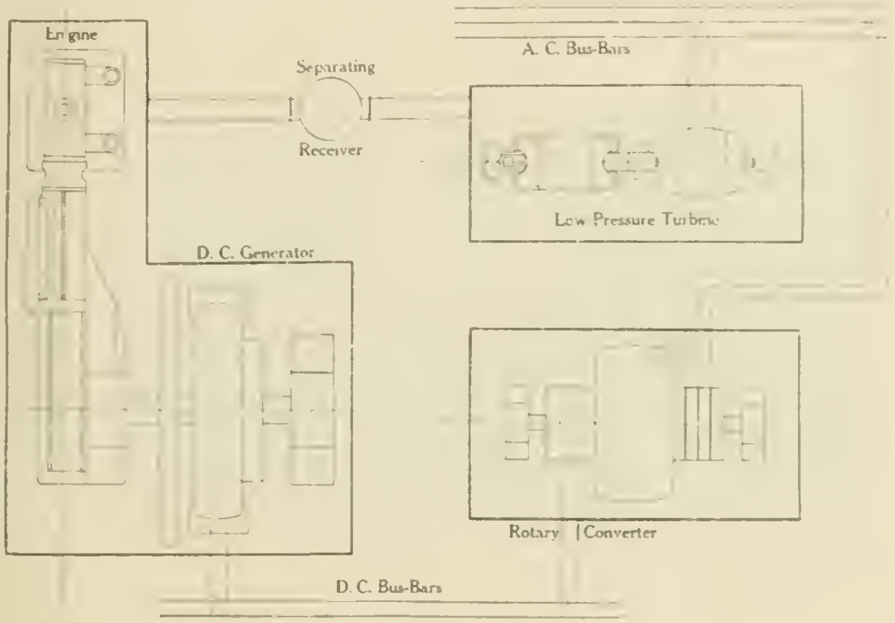

FIG. 4—DIAGRAM ILLUSTRATING CASE "C"

alternating current operation, amounting probably to ten percent. In the majority of cases, however, the direct-current engine load will predominate over the alternating-current demand, and the demand on the converter will be uni-directional, in which event lighting could be satisfactorily served. Even in the previously mentioned case, the use of separate excitation in conjunction with a Tirril regulator for the motor-generator set will remedy the difficulty of voltage variation.

Another method of solving the same general problem is to connect with the reciprocating engines, directly or by belt, a synchronous generator in multiple with that driven by the low pressure turbine. This synchronous motor must have sufficient capacity for the maximum unbalancing of the direct and alternating-current loads. By making use of this expedient the reciprocator automatically takes sufficient steam for the needs of the whole system with maximum economy and quite ideal regulation, at the same time satisfying the primary requirement that under no condition of operation shall steam escape to atmosphere.

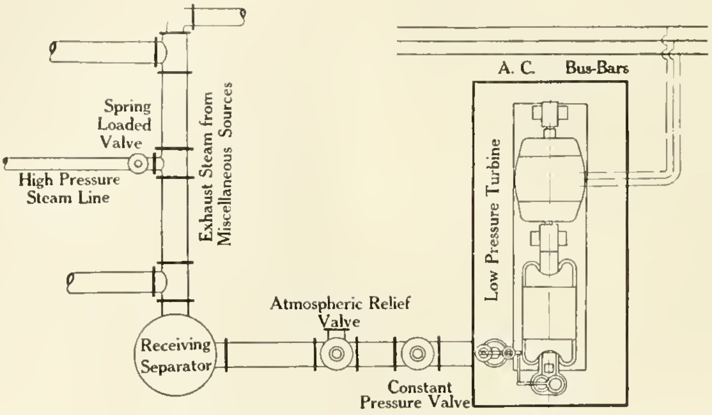

FIG. 5—TURBINE RECEIVING EXHAUST STEAM FROM MISCELLANEOUS SOURCES, ACCORDING TO CASE "D"

CASE D

Many plants contain a large number of engines, pumps or other steam-using prime movers which do not drive electrical apparatus. The exhaust from these may be collected and brought to a common point at which it is used in a low pressure turbine controlled by a governor, as shown diagrammatically in Fig. 5. In such installations when the demand of the turbine for steam is greater than the amount supplied by the various sources, the pressure in the piping system will fall until it becomes less than that of the atmosphere, and under this condition the inleakage of air is practically unavoidable. It is, therefore, essential to place a constant pressure valve in the low pressure steam line adjacent to the turbine, thus insuring the maintenance of a pressure in this line slightly greater than that of the atmosphere, even at such times as the available amount of exhaust steam is not sufficient to so maintain it if the turbine were drawing from this line. A considerable saving can generally be effected by this expedient since it makes unnecessary a large investment for a heavy pipe line to prevent such leakage. A relief valve should also be fitted to the line so that any steam not used by the turbine will escape to the atmosphere. As the service in this case may be such that the supply of exhaust steam is not always sufficient to carry the load imposed on the turbine, an auxiliary valve, under the control of the turbine governor, should be provided to admit live steam to the turbine when necessary. At first glance the use of live steam in a turbine designed for low pressure work would appear to be poor engineering, but in general this is not the case. The fact that the supply of low pressure steam is insufficient generally indicates that some of the reciprocating apparatus has been relieved of its load, and since the boiler plant is producing steam at a rate sufficient to carry the former load on the reciprocators, the safety valves will soon blow unless steam is used in some way or other. Its admission to the turbine will prevent this condition from arising, unless the turbine load also is considerably reduced. It is, therefore, quite frequent practice to pipe the safety valves on the boilers into the low pressure system between the engines and the turbine. Fig. 6 shows a plant of this type.

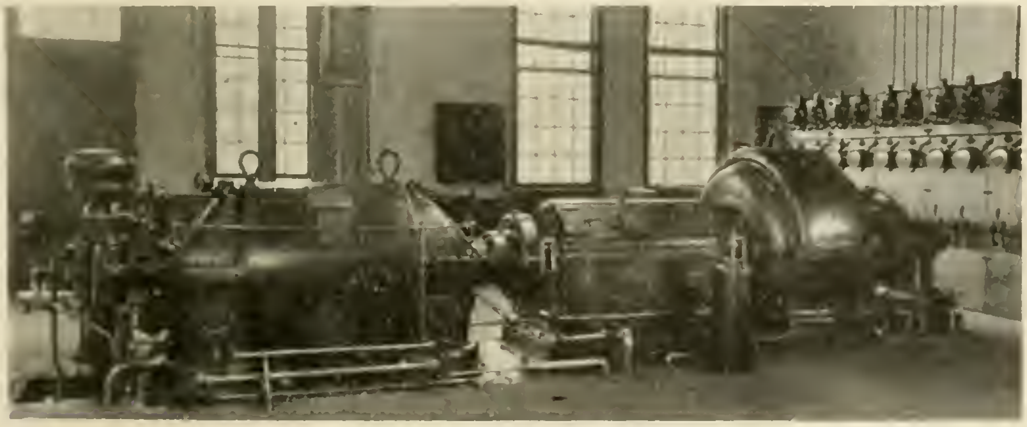

FIG. 6—LOW PRESSURE TURBINE DRIVING A DIRECT-CURRENT GENERATOR THROUGH REDUCTION GEARS

An example of Case *D*

Conditions such as these are most frequently found in rolling mills or hoisting sheds where the reciprocators are in intermittent service. If, however, there is a larger proportion of the time when it is desired to operate such a turbine on high pressure steam, the correct solution is that of *Case H.*

CASE E

There are numerous plants where the engine and turbine loads are independent or cannot be yoked together. Thus the load on the turbines may be very much lighter than that on the reciprocating engine, and if the installation were made as in *Case D,* the excess of steam from the reciprocating engines would escape to the atmosphere and be wasted. *Case E,* therefore, makes provision for operating a reciprocating engine partially condensing under such conditions. The turbine governor controls a valve which, instead of admitting steam to the turbine, allows the exhaust from the reciprocator to pass to the condenser. If there is no load at all on the turbine, this valve would stay wide open and the engine would operate with substantially full vacuum. As the turbine load increases, the governor tends to close this valve, making a sufficient difference between the inlet and exhaust pressures of the turbine so that the desired load may be carried. Finally the governor valve may be entirely closed, thus forcing all the steam from the reciprocator to pass through the turbine. Obviously the advantage of an arrangement such as shown in Fig. 7 is that whenever the load on the turbine falls below normal, the reciprocating engine will obtain the benefit

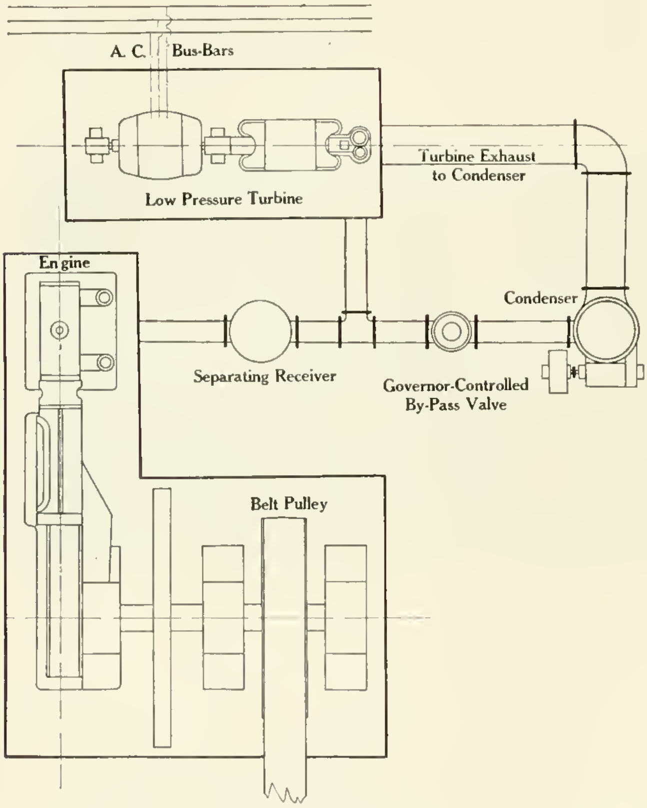

FIG. 7—ENGINE AND TURBINE CONNECTED ACCORDING TO CASE "E"

of some vacuum. The turbine inlet is, of course, provided with a butterfly valve connected to the governor so that the turbine will be prevented from running away if the load be entirely removed, or if for some external cause the reciprocators pass an inordinate amount of steam which could not get through the by-pass without a material rise of pressure in the exhaust steam line. In some cases the installation described might be better arranged by treating it as *Case C,* using a synchronous generator tie.

CASE F

This, as indicated in Fig. 8, is a modification of *Case C* and has found a wide application among the cotton mills of New England.

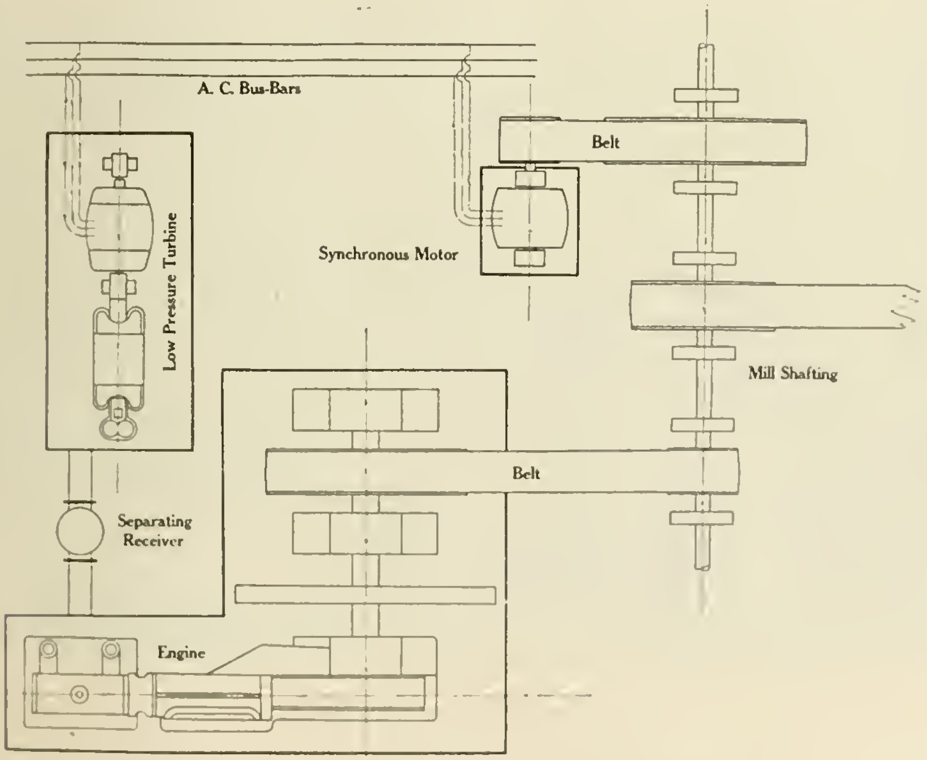

FIG. 8—DIAGRAM ILLUSTRATING CASE "F"

It is again a case where the low pressure turbine and reciprocating engine loads are entirely different, but a tie may be established between them and in this way all the exhaust steam used. As in *Case A* the turbine normally operates without a governor, although generally one would be fitted to provide for operation should the reciprocating engine go out of service. An ideal case of such an installation is found where the reciprocating engine is driving a mill through line shafting and it is desired to enlarge the mill, using motor drive for individual machines, or to increase the power plant capacity for any purpose. The low pressure turbine is installed and electrically connected to a synchronous motor belted, or otherwise connected, to the mill shafting. This synchronous motor will either take energy from, or give energy to the mill shafting in accordance with the varying demands of the power and electrical systems. Should the mill load increase, the governor on the reciprocating engine will admit more steam, which will pass through to the turbine. The excess power from the turbine is delivered to the mill shafting through the synchronous motor. An increase of the motor load driven by the low pressure turbine means that it will tend to slow down and energy will be taken from the mill shafting by the synchronous machine whereupon the reciprocating engine governor will admit more steam to the engine. If all the energy from the low pressure turbine is to be employed in driving the mill and the purchaser does not desire to operate motors or lighting circuits, the turbine may be connected to the mill shaft directly through gears and all the advantages of the *Case A* installation may be realized, the connection being mechanical instead of electrical.

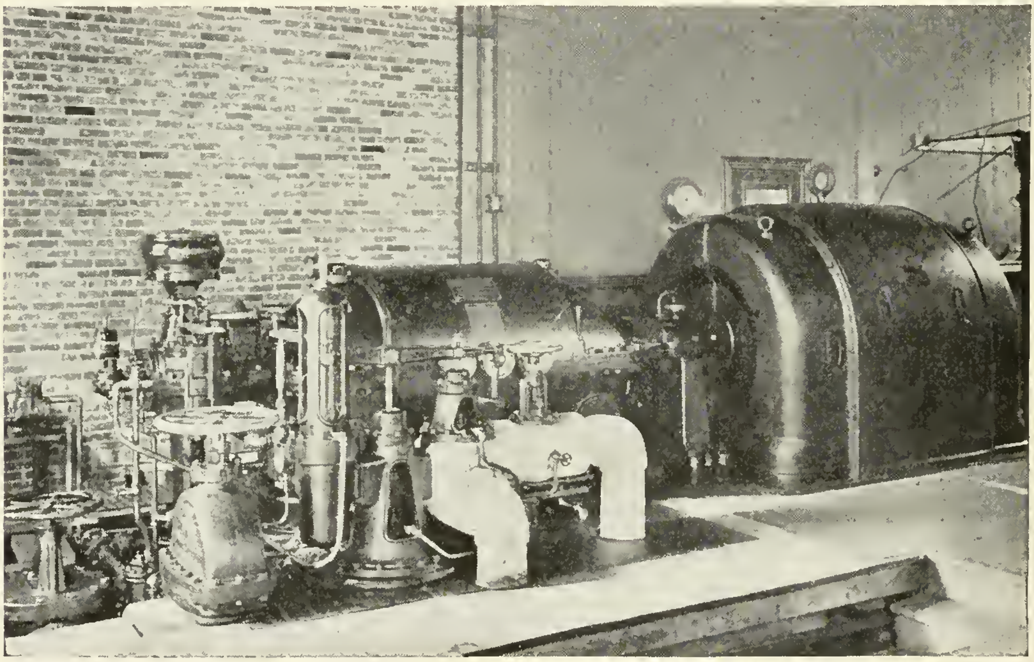

FIG. 9—750 KW "CASE F" INSTALLATION EQUIPPED WITH GOVERNOR

CASE G

Where the supply of the exhaust steam is obtained from rolling mill or hoisting engines and is, therefore, quite variable, there may often arise a condition where there is a complete cessation of the flow of exhaust steam. To continue the operation of the turbine, it will, therefore, be necessary to supply live steam or else employ a heat storage means, such as a regenerator, of sufficient capacity to bridge over the period when no exhaust is being furnished by the engines. This case, as illustrated in Fig 10, will be recognized as an elaboration of *Case D,* differing only in that means are provided for storing heat when an excessive exhaust steam supply is available and giving up this stored heat when there is an insufficient supply. The regenerator consists generally of a large vessel partially filled with water through which the exhaust steam passes on going from the reciprocating engine, the water being thus maintained at the temperature of the steam. It is usual to design a regenerator to operate between the limits of atmospheric pressure and 5 or 10 lbs. gauge, the lower limit being selected in order to avoid the possibility of inleakage of air. To indicate the action of a regenerator, the following actual case may be cited:

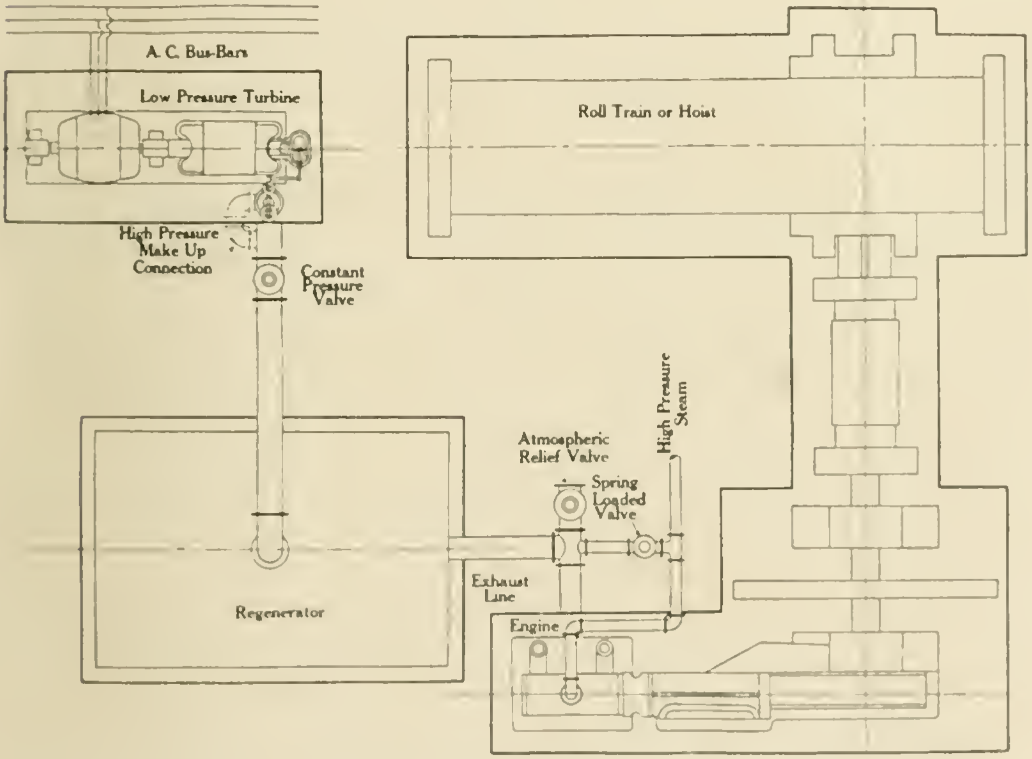

FIG. 10—DIAGRAM ILLUSTRATING CASE "G"

Assuming that the pressure limits for its operation are 14.7 lbs. and 25 lbs. absolute, i. e., atmospheric pressure and 10 lbs. gauge, the corresponding temperatures will be 212 and 240 degrees F. Assume that the water in the regenerator is at 212 degrees and the steam at a corresponding pressure, and that the steam delivered by the reciprocating engine is exactly equal to the demand of the low pressure turbine. So long as this condition exists, the steam flows through the water in the regenerator and no heat is taken up or given out. Now, assume the load on the reciprocator, and consequently the amount of steam it discharges, to increase while the demand of the turbine for steam remains constant. Then the pressure within the regenerator and accordingly the temperature of the steam, will begin to rise, resulting in an increase in the temperature of the water if provision is made for intimately mixing the steam with it. As the pressure increases, the steam comes in at a temperature higher than the water and is so in part condensed, which assists in maintaining the temperature of the water corresponding to that of the steam. This process may continue until the pressure within the regenerator reaches 25 lbs., at which point the relief valve has been set. Under these conditions, each pound of water within the regenerator will have absorbed 28.3 heat units. Now suppose the flow of exhaust steam from the reciprocating engine to absolutely cease, in which event the pressure within the regenerator begins to fall because the turbine continues to draw steam from it. When this pressure has reached 14.7 lbs., the water in the regenerator will have evaporated until its temperature corresponds to that of steam at this pressure, i. e., 212 degrees and each pound of water in the regenerator will have given out 28.3 heat units, the equivalent of the amount of absorbed while the pressure was rising. The mean latent heat of evaporation through this range being 961 units, each pound of water so reduced in temperature will liberate 0.0294 lbs. of steam. Obviously, in installing a regenerator, the important point to determine is the length of time the regenerator will be expected to carry full load on the turbine without any supply of steam from the engines. From the above figures it will be seen that if this is long, the quantity of water within the regenerator must be very great. Then again the pressure limits assumed in the above example were quite wide. In a good many installations it would not be possible to impose 10 lbs. back pressure on the reciprocating engines. Reference to this matter is made because generally the disposition of a prospective installer of a regenerator is to make the time element much greater than is necessary. Some early installations of regenerators provide for six to seven minutes of operation without a supply of exhaust steam, whereas six or seven seconds would have been better. For instance, in steel mill practice, if the exhaust from a blooming mill engine is to be considered, the time element should bear reference to the period between the passes of an ingot, and to the maximum time from the last pass of one ingot to the first pass of a new ingot, and the regenerator should not be designed to cover such delays as would arise due to the clogging of the mills or because a new ingot might not be ready to be bloomed.

As was indicated in *Case D,* there is another source of exhaust steam available when such an unforseen interruption arises. The boiler plant is being fired continually, and if the demand for steam is interrupted in this unusual way, the safety valve will blow. The steam escaping in this way should be led direct to the regenerator so that the turbine will continue to carry its load without drawing live steam. The best method of providing for this is a cross-connection between the steam and exhaust lines of the engine in which is placed a spring-loaded valve set to blow at a few pounds lower than the safety valve. There will always be periods of more or less duration when the regenerator cannot furnish enough steam for the turbine and the only alternative is to supply live steam. This has been frequently accomplished by admitting steam to the regenerator through a reducing valve so set that when the pressure within the regenerator reaches the lower limit, steam will be admitted. Such valves are, however, generally unsatisfactory and troublesome, and it is better practice to employ for this purpose the secondary or live steam valve under control of the turbine governor. This valve may be arranged to admit steam either to the inlet side or outlet side of the regenerator. If admitted to the inlet side, no water hammers will be produced, a condition which might arise with admission on the outlet side if the regenerators were arranged for wide pressure limits. The disadvantage of admission on the inlet side, however, is that the pressure in the regenerator cannot be raised without condensing steam therein, thus necessitating supplying a large amount of live steam to tide over temporary heavy loads on the turbine. In such an arrangement it is conceivable that when the exhaust steam again flows into the regenerator the latter being already partially charged, it will be unable to absorb all of the supply and some of it will pass through the relief valve to the atmosphere, thus violating the primary consideration for which the regenerator was installed. If live steam is to be admitted, therefore, and the regenerator is arranged to work within wide limits, arrangement should be made to admit it between the turbine and regenerator. It may prove desirable to install a check valve between the point in the pipe where the live steam is admitted and the regenerator so that if the regenerator were at the lower pressure limit and no steam was being admitted to it, and the load on the turbine was such that more steam was required, the pressure in the regenerator would not be raised without the temperature of the water rising correspondingly. Obviously, if the pressure in the regenerator were raised by admitting steam in the reverse direction, that is, without passage through the water, from the secondary valve on the turbine, then when steam comes from the reciprocating engines in the usual direction, it would be at a temperature higher than that of the water within the regenerator and might cause hammering, the violence of which would correspond to the temperature difference.

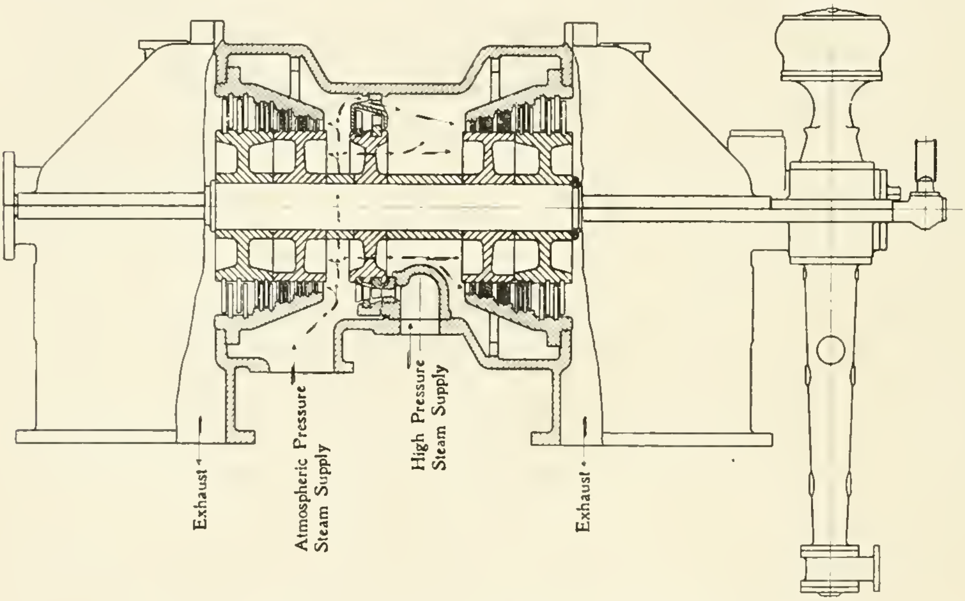

FIG. 11—SECTIONAL VIEW OF MIXED PRESSURE TURBINE

CASE H

Occasionally the conditions in a plant are such that it is desirable to utilize a quantity of exhaust steam which is intermittently available, but there are also long periods of time unrelated to this supply over which the output of the turbine is desired and when it would, therefore, be preferable to arrange to operate on live steam. Or again there may be constantly available an amount of exhaust steam insufficient to carry the average load on the turbine. The simple low pressure turbine does not have a high efficiency when operating with live steam, and in this case, therefore, a special type of machine is employed. This is commonly called the mixed pressure turbine; but as used here, this expression refers specifically to a turbine having a separate high and low pressure element in one cylinder. All such turbines of course, are fitted with governors and special valves arranged to supply high pressure steam to appropriate nozzles when the supply of exhaust steam is insufficient or fails entirely. The steam is then expanded in the high pressure nozzles and its expansive energy absorbed down to the pressure at the inlet to the low pressure elements. Such a turbine is obviously the same as any other low pressure turbine fitted with a governor and live steam valve, except that the live steam passes through the high pressure element before entering the low pressure section. A large number of applications of such a mixed pressure turbine may very conveniently be made where the exhaust steam available comes from pumps or other apparatus of that kind, but it is generally not suited for work in large sizes, the most economical solution of the problem being afforded by the use of a small low pressure turbine and another complete expansion machine to give the necessary capacity. Again a solution of the problem may be found in *Case C* or *F*. It should be remembered that the high pressure element revolving without doing work when the turbine is running on exhaust steam, is a source of loss amounting to at least two percent; and further than this, it adds a complication to what has been previously pointed out as an inherently simple machine. In cases where they are desirable, the construction consists of an impulse element in which the energy of expansion to approximately atmospheric pressure is absorbed, the remainder of the energy being taken out through reaction low pressure elements. A sectional view of such a machine is shown in Fig. 11. The control valves are so arranged that no high pressure steam is admitted until the low pressure valve is fully open, or in other words, until the turbine is unable to carry its load with the available supply of exhaust steam. There may occasionally arise a case where a mixed pressure turbine could be used, as in *Case G*, in which event the check valve indicated as desirable should not be omitted.

THE FORMATION AND ORGANIZATION OF A LARGE MANUFACTURING CORPORATION

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*This article is based on the first of a series of lectures on "Works Management," delivered at The Westinghouse Club. In selecting the lecturers the main object was to secure men who are authorities on the subjects under discussion. The lectures were prepared with the primary intention of explaining the general subject of works management in plain language to a large group of comparatively young men. They are presented to JOURNAL readers in the belief that they will prove of general interest and value.—(ED.)

IT is assumed that a number of men, either capitalists themselves or controlling capital, have met together and decided to form an organization for the manufacture and sale of electrical apparatus, believing of course that in so doing, profit may be made. The only reason any business concern has for its existence is to make profit for its stock-holders; and, the greater the risk, the greater should be the ultimate returns, if the venture prove successful. For any manufacturing concern to be successful, certain fundamental conditions must be met, principal among which may be mentioned the following:

1—There must be a market for the sale of the goods which it is proposed to manufacture.

2—There must be a market in which to purchase the necessary raw materials and supplies.

3—There must be suitable transportation facilities for the raw materials and supplies, as well as for the completed apparatus; these two, though usually the same, are occasionally quite different.

4—There must be labor available with which to manufacture.

5—There must be capital with which to purchase labor, materials and supplies.

All these points require the most careful consideration; in addition, climate is sometimes a most important factor. The tendency has been for a manufacturing plant to locate near the source of raw materials; for example, iron and steel mills near the coal or iron supply; flour mills adjacent to the wheat fields; cotton mills

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*This lecture was taken in part from an article by the author in the *Sibley Journal of Engineering,* February, 1912.

in the midst of cotton fields, especially since an artificially moist atmosphere can now be created in the mills; fish canning industries on the river banks or ocean shores. However, with cheaper and cheaper transportation and electric power costs, this tendency to seek the raw material field is not quite so important and other considerations may outweigh it, such as the vicinity either of the labor market or of the market for the disposal of the finished product. Take Pittsburgh and the steel industry—though the best location up to the present, the indications are that with the upbuilding of the West a better location in the near future would be in the vicinity of Chicago, because the labor market is as good, the increased haul of coke is balanced by the decreased haul on ore, and the average haul on the finished product would be considerably less.

Since it has already been assumed that an organization is to be formed, it is quite evident that the men who are willing to risk their money in the enterprise have canvassed the situation and feel convinced that all of the conditions stated can be fulfilled. It is now further assumed that the new organization will be a corporation and not a partnership. The advantages of one over the other are in part as follows: A corporation is a separate thing, quite apart from any of the individuals belonging to or composing it; its functions are not necessarily disturbed either by the death or withdrawal of any individual, whereas a partnership is usually terminated thereby; it invariably has a charter which gives it legal standing, while in a partnership the agreement may be implied, not written, and may even exist without the knowledge of some of its members; in a corporation the individuals cannot as a rule be called upon to assume any of its debts, but in a partnership each member may be held responsible for all of the debts; a corporation's shares can be sold, transferred or loaned by the individual owners; in a partnership, no money can be borrowed on the strength of a member's interest; the management of a corporation is vested in a board of directors with limited powers, who must make periodic reports to its stock-holders; in a partnership each partner may act with unlimited powers and without the consent or knowledge of the other partners.

A name is now selected for the corporation, plans are drawn up outlining its scope as regards capital stock, incorporators, lines of manufacture, duration of charter, location, etc. and a state charter is applied for, the application being filed with the secretary of state. At least three persons, and in some states five or more, are required to form a corporation.

The statutes of the various states, in order to expedite business, now provide for the formation or incorporation of stock companies, or corporations, as they are more commonly called, though formerly they were required to be authorized by direct act of legislature. A license, not a charter, is next issued, authorizing books to be opened for subscriptions to the capital stock. A certain minimum amount is usually required to be subscribed and paid for, a meeting of subscribers held, directors elected, by-laws made and a record of all these proceedings filed with the secretary of state, before a charter is granted authorizing the transaction of business under the laws of the state. This charter is issued primarily for the purpose of bringing in revenue to the state, not only when granted but annually thereafter, as a rule; and the tax which must be paid for it is based largely on the capital stock, though also to some extent on the kind of business to be entered. In years gone by, when it was desired to attract capital to a state, and thus to develop its resources, the conditions imposed on business were much less severe than now. As an instance of this, it may be stated that what were known as "blanket" or "omnibus" charters, were sometimes issued, permitting a company to engage in any sort of business whatsoever. A charter of this kind could hardly be obtained in these latter days, under any conceivable circumstances, so it may be appreciated that such a charter is a valuable asset in itself.

As already mentioned, the state tax is based largely on the capital stock, and it is therefore the part of wisdom for the promoters, as good business men, to keep the capital stock as low as possible for the time being, even if later on it be necessary to increase it. Though practically every manufacturing concern must have a charter, it is not necessary that this be obtained in the state in which the works are to be located. Since this is so, many concerns obtain their charters in states in which the tax on their capital stock will be the lowest, and this is one of the reasons, though not necessarily the principal one, why so many charters have been taken out in New Jersey.

Upon the granting of the charter, and the completion of other equally important arrangements which it is not requisite to detail here, the corporation is ready to organize on more permanent lines. The first officers are usually selected from among the men who first contribute toward the capital stock, and who are naturally, therefore, the original stock-holders, though occasionally, when temporarily desirable not to disclose the identity of the real promotors, dummy officers may be installed. At the proper time these dummies resign one after another, the real officers then being appointed, usually by the board of directors, to fill the vacancies. At this time also, a new board of directors may be elected. The members of the board are not elected permanently, but usually for stated periods, though all of them may stand for re-election; it is not necessary for the members of the board to own personally all, or even a majority of the stock; but, where such is not the case, they must at least control its voting power. The executive officers consist of the chairman of the board of directors, who is invariably the ranking officer, the president, one or more vice-presidents, the secretary, the treasurer, and the auditor; but it does not follow that (the chairman excepted) they are necessarily members of the board, though frequently some of them are. In certain concerns, there may also be an executive committee reporting to the chairman. The officers in turn choose the departmental heads, including the managers of sales, engineering, works, etc., and these in turn complete their respective departments. Though the proceeding has been rapidly outlined, it does not follow that the officers named are all chosen at one time, nor need they be separate and distinct. The president may perhaps be manager of one or more departments as well, the treasurer may combine with his work the duties of secretary, the auditing department may consist

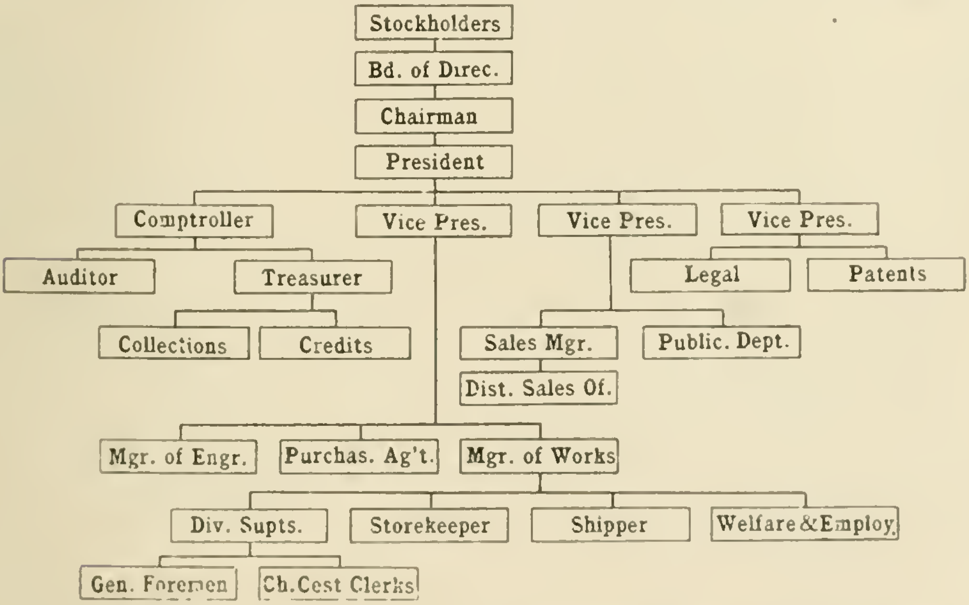

FIG. 1—ORGANIZATION OUTLINE OF A MANUFACTURING CORPORATION

of but a bookkeeper, and so on. A large manufacturing concern will eventually have, however, an organization somewhat along the lines shown in Fig. 1.

With the growth of its business, a corporation sometimes finds it advisable to increase its capital stock; and this is accomplished, either by the issue of additional shares of the same kind as the original, or by creating a new kind, in which case the original is generally called preferred or first preferred, and the second, common or second preferred. Sometimes, rather than increase the capital stock, mortgages, occasionally designated as debentures, or bonds, may be issued with a part or the whole of the plant as security. Of course any move of this kind to raise money must receive the sanction of the stockholders before it can be put into effect. Of the two methods the latter, that is, the issuing of mortgages or bonds, is perhaps to be preferred, for the reason that the debt is sooner or later wiped out, when the interest which it has been necessary to pay during the life of the mortgages or the bonds can be applied in other ways; whereas, the payment of interest on stock is a perpetual obligation even though a concern be not always successful in meeting it. The money thus raised by a corporation may be used for the erection and equipment of additional buildings, the further purchase of machinery or of the patents and good will of another manufacturing concern; it may be used for the cancelling of outstanding obligations, such as the payment of maturing notes and bonds, or it may be used in various other ways.

From what has thus far been told, it will be inferred that the stockholders are the ultimate authority in every corporation. The board of directors is elected by them, except possibly at its formation; and accordingly, must inform them regularly as to the conduct of the business. This is usually done through the medium of annual, semi-annual or quarterly reports, which give in a very complete, yet condensed form, certain essential information such as a statement of the work undertaken and accomplished, as well as an outline of prospective business and new fields of activity. The assets, liabilities, income, profit and loss, are also set forth. If these statements are not considered satisfactory by the stockholders, it is within their power, by voting their disapproval at one of the stockholders' meetings, to change the board of directors, or to make any other changes they may deem necessary or desirable. In voting, each share of a kind, usually counts one vote. It is not a question of individuals but of votes; in other words, a single stock-holder, by possessing or controlling a majority of shares, may dictate the policy of the corporation.

The principal features of the reports made by the directors to the stock-holders are, in large measure, compiled from regular monthly statements issued by the various departmental heads to the executive officers. Most of the financial information contained in them is obtained through the medium of the accounting department, under whose charge are placed practically all of the financial accounts. Where such is not the case, they at least exercise supervision over the methods employed.

SAMPLE BALANCE SHEET

ASSETS	LIABILITIES
Property and Plant	Capital Stock
Real estate, Buildings, Machinery, Equipment.	Preferred, Common.
Quick Assets	Current Liabilities
Accounts receivable, Notes receivable, Interest accrued, Cash.	Accounts payable, Notes payable, Interest accrued, Taxes (accrued but not due).
Working Assets	
Raw materials, Work in progress (in factory and in course of erection at destination.) Finished stock and apparatus.	
Investments	Funded Debt
Bonds (in other companies), Stocks (in other companies).	Bonds, Mortgages.
Miscellaneous	Miscellaneous
Charter Patents, Furniture, Fixtures, Taxes (paid in advance), Insurance (paid in advance).	Adjustment Reserves.
	Profit and Loss
	Surplus.

It will be advisable now to examine into the several statements just referred to, as being submitted by the directors to the stock-holders, in order to see how they are made up, and in so doing to learn a little more in detail of the methods of any large corporation. Every concern not only extends, but it receives credit; in other words it owns as well as owes. Were this not so, the business of the world would be very much restricted. What a concern owns is called its assets, what it owes is called its liabilities. Discussing the assets and liabilities, which appear on what is known as a balance sheet, it may be seen that it is issued in ledger shape, the left hand column giving the assets, the right hand the liabilities. Taking the assets first, these may be divided into several groups—Property and plant, quick assets, working assets, investments, miscellaneous, each in turn being further divided into various items. Included in property and plant are the grounds on which the works are located, as well as any other property of a like nature which the corporation may hold; also, the buildings occupying these grounds and the machinery or other equipment which may be either on the ground or within the buildings. Quick assets mean exactly what the term implies, either money itself or available assets which, if occasion makes necessary, may be converted into money quickly. These, therefore, consist of accounts and notes receivable, representing either customers' accounts that have not been paid or for which interest bearing notes have been given and which may, therefore, be readily discounted at a bank or other medium of exchange; also interest due from cash in bank or from other sources, and finally, cash in bank or on hand. Under the head of working assets, sometimes known as trading assets, are placed raw materials, work in progress, consisting of apparatus in course of completion in the works or at destination, and finished stock and apparatus. In the line of investments may be mentioned bonds and stock in other companies—these are acquired sometimes by purchase, sometimes in part payment for apparatus furnished. The items grouped under the head of miscellaneous, namely, charter, patents, furniture, fixtures, taxes and insurance, are sufficiently plain without explanation—taxes and insurance are only included when paid in advance. Attention is especially called to the two items, charter and patents, which occasionally are the very life of a concern and which may, therefore, be set down sometimes in large figures.

Turning next to the liabilities, the very first item, and usually, though not always, the largest, is the capital stock. This is a liability because of the shares having been sold to the stockholders. Under current liabilities come such items as accounts and notes payable, interest due on same, taxes and insurance—the last items included only when accrued but not yet due or paid. The next liability is that of funded debt, meaning a secured debt; for example, money raised by bonds and mortgages and pledging the property or plant as security. The item under miscellaneous called reserves is an amount set aside to cover certain kinds of depreciation, like bad debts, or the loss on material or stock purchased or acquired which has lessened in value since its purchase, and so on. Totaling up all of the assets and likewise all of the liabilities, and subtracting the one from the other, the difference will represent either a surplus or a deficit—a surplus if the assets are the greater, and a deficit in the contrary case. As the balance sheet is a ledger account and must therefore be a balanced statement, when the assets exceed the liabilities, the difference or surplus is placed below the liability column; on the other hand, when the liabilities exceed the assets, the difference or deficit is placed below the asset column.

INCOME AND PROFIT AND LOSS STATEMENT.

Gross Earnings.	Cost of Shipments.
Shipments billed.	All expenses including factory cost and expenses of patterns, dies, tools, inventory adjustments, selling, etc.
	Net Manufacturing Earnings.
	Profit.
	Deductions.
	Depreciation on property, plant and materials.
	Net Profit from Manufacturing Operations.
	Profit.
Other Income.	Deductions from Income.
Interest on notes receivable. Dividends on stocks and bonds in other companies. Royalties.	Interest on bonds and mortgages. Interest on notes payable. Discount on bills receivable. Sinking fund charges.
	Net Income.
Net Inoome.	Surplus for the year.
Surplus for the year.	
Profit and Loss Credits.	Profit and Loss Charges.
Surplus from preceding balance sheet. Profits on bonds and mortgage certificates purchased and retired. Miscellaneous.	Dividends on capital stock. Depreciation on securities owned. Miscellaneous. Surplus as per balance sheet.

While the balance sheet shows in part the financial condition of the corporation, it still needs to rounded out by what is known as the income and profit and loss statement. As its name implies, this gives the sources of income of the corporation and its net profit or loss for the year. For convenience in explaining, it has been set down with the income on one side and the "outgo," (if the liberty may be taken of calling it such) on the other. On the income side, the first item is that of gross earnings, this including the total value of all shipments billed to customers. On the outgo side, the first item is the cost of shipments billed, meaning by this the total cost inclusive of everything, namely, factory cost, with expenditures for patterns, dies, tools, inventory adjustment, also selling, administration and other sources of expense. The difference between these two sets of figures gives the net manufacturing earnings, which may be either a profit or a loss. There are still certain deductions to be made from the net manufacturing earnings, these consisting of the depreciation on property, plant and materials. When such have been allowed for, the remainder will then indicate the net profit (or it may be the net loss) from manufacturing operations.

Reverting again to the income side of the statement, it will be seen that besides manufacturing profits, there are other sources of income, consisting of interest, and dividends due from investments of one kind and another, royalties, etc., while to offset these, there will be found on the outgo side of the statement deductions, including interest payable on bonds, mortgages, notes, etc., also discounts on bills receivable and sinking fund charges. If these be respectively added to and subtracted from net profit from manufacturing operation, the result will be the net income or the surplus for the year. If to this be added next, certain credits, such as profits on bonds or mortgage-certificates of the company which have been purchased and retired, provided there are any such; and, likewise if from this total be subtracted certain charges or debits, as dividends on the capital stock of the corporation, depreciation of securities owned or of accounts receivable, etc., there is finally left a surplus (or a deficit), which will be in accord with the surplus or deficit shown by the balance sheet.

THE CONSTRUCTION OF ELECTRICAL HEATERS

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ELECTRICITY is changed into heat in four different ways:—

First, by the Joulean Effect
Second, by the Electric Arc
Third, by the Electric Spark, and
Fourth, by the Electrolytic Effect.

The Joulean Effect, changing the electrical energy into heat on account of the electrical resistance of the circuit, is limited to devices requiring temperatures not higher than the resistance material of the resistor will stand. While temperatures as high as 5 500 degrees F. can be obtained, it is only in furnaces, welding machines and a few other devices that temperatures in excess of 1 200 degrees F. are required. All domestic, commercial, and most scientific and industrial heating devices belong in this class.

The Electric Arc makes possible the use of the highest artificial temperatures known, ranging as high as 6 500 degrees F. These temperatures cannot be reached in any other manner and they make possible the production of materials which formerly either were not known at all or which could not be obtained artificially. The electric arc furnace is the principle representative of this class of heating devices.

The Electric Spark is mostly employed for igniting explosives for blasting and the explosive gas mixtures in combustion engines. In either case it is accomplished by the spark plug, a device well known to everybody since the automobile has come into general use

The Electrolytic Effect is employed in electrolytic cells when the electrical energy is partly changed into chemical energy required for the chemical process in the cell and partly changed into heat. In case the process requires an elevated temperature, then this heat is used to provide this high temperature.

As large as the variety of electrical heaters in practice is, they represent only a few different types and it is the intention to point out these types in the following lines.

JOULEAN EFFECT

The Incandescent Lamp is probably the best known type of heater. The filament, preferably of carbon, made to glow in a vacuum, radiates heat. In most cases special long bulbs of 250 or 500 watts capacity are used, as shown in Fig. 1, and they are arranged in groups of two, three or more in accordance with the amount of heat required. The incandescent lamp represents one of the best, if not the best heater which transmits its heat by radiation. While incandescent lamp heaters were employed for quite a number of heating appliances, even inside of cooking utensils, their use is now practically restricted to appliances where light and heat are utilized jointly, such as in luminous radiators and in therapeutics.

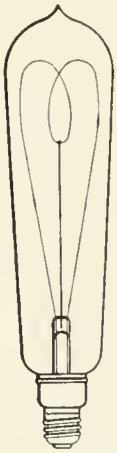

FIG. 1—LUMINOUS RADIATOR HEATING UNIT

The Exposed Wire Heater is another well known type of resistor. A resistance wire, straight or in the form of a helical coil, heated by the electric current, is either hung up free in the air or wrapped around a spindle of insulating material, such as porcelain, as shown in Fig. 2. The cold air, striking the hot wire, carries the heat by convection into the car, room, oven or other space which is to be heated. In early days, heaters of this kind could only be used for low temperatures, such as required for heating air, because the resistance wire, if heated above a few hundred degrees, would oxidize and burn out after a short time, unless expensive platinum was employed. Since the discovery of special resistance metals, such as nickel-chromium, temperatures as high as 1 750 degrees F. can be maintained without injuring the wires. The result is that heaters of this type are now being used for quite a number of different devices, such as street cars, foot-warmers, incubators, hair dryers, toaster stoves, grills, broilers, furnaces and others. For temperatures above 1 750 degrees F. and up to 2 750 degrees F., platinum has no competitor as yet and therefore is still being used for certain furnace work. Besides this it is employed for dental and surgical purposes,

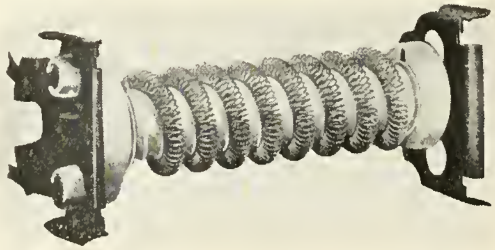

FIG. 2—EXPOSED WIRE HEATING UNIT

such as in cauterizing instruments, hot air syringes and many other similar appliances, where price enters as a secondary consideration only.

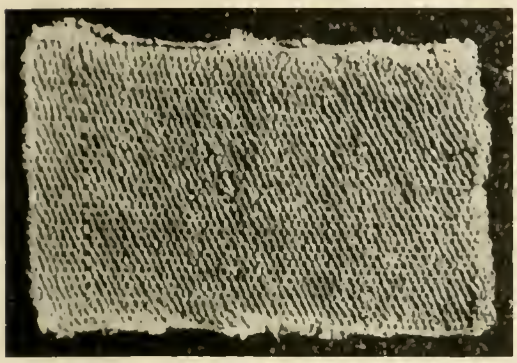

FIG. 3—INSULATED WIRE HEATING UNIT

In a great many cases it is impossible to use exposed wire heaters and the wire must be electrically insulated in one way or another, to prevent short-circuits. This is accomplished in a number of instances by covering the wire with some fireproof electrical insulating material, such as asbestos. The wire can then be arranged without any spacings between its different sections, but of course the heat generated must pass through the covering before it can act on the object to be heated. Insulated resistance wire heaters can be found in heating pads, as shown in Fig. 3, foot-warmers, air heaters, and similar devices. The principal field is for devices which must be flexible, like heating pads, and in which the temperature required does not exceed a few hundred degrees. With the exception of asbestos, however, there are few fire-proof electrical insulating materials suitable for covering wires, and which, at the same time, have flexibility, so that they will bend with the wire, without being damaged.

Another successful method of insulating resistance wire electrically is to embed it in cement, fire-clay, carborundum, fire-sand, or other fire-proof material, as shown in Fig. 4. In this manner, the different sections of the wire are not only insulated from each other, but the air is excluded at the same time, preventing oxidizing and burning out. This was of especial importance before nickel-chromium wire was available. As in the insulated resistance wire heater, the current heats the wire and the heat passes by conduction through the electrical insulation into the material, which is to be heated. Embedded resistance wire heaters are employed in all kinds of domestic and industrial appliances, such as

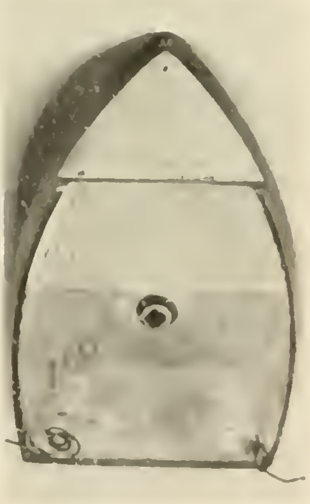

FIG. 4—EMBEDDED WIRE HEATING UNIT

cooking utensils, air heaters, laundry irons, glue pots, water heaters, ovens and furnaces. With nickel-chromium wire embedded in the proper materials, temperatures as high as 1 750 degrees F. can be produced, and with platinum, temperatures as high as 2 750 degrees, covering practically the entire heating field.

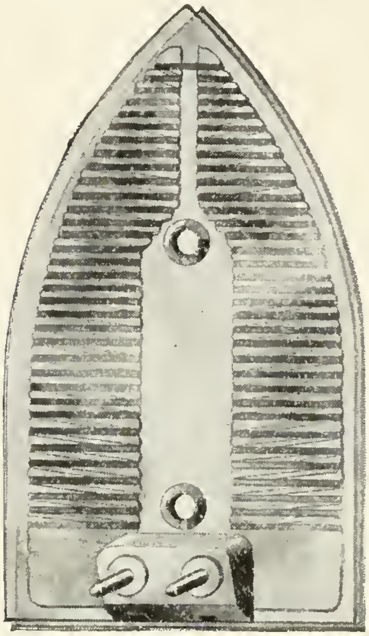

FIG. 5—HEATING UNIT WITH WIRE WRAPPED AROUND AND PLACED BETWEEN SHEET MICA

Embedding the resistance wire means that all the heat must pass through the insulating material, which very often is of considerable thickness and which, at the very best, cannot be used thinner than 0.015 in. As all electrical insulating materials are more or less excellent heat insulators, a loss of heat is suffered. In order to reduce this loss to a minimum, heaters are now being made by wrapping resistance wire around a thin sheet of mica and clamping it tightly between the metal parts which are to be heated, as shown in Fig. 5. As mica can be used as thin as 0.005 in., considerably less heat is lost than in the embedded wire heater and the efficiency is increased proportionately. It is only since the development of the nickel-chromium wire, which makes the exclusion of the air of secondary importance, that this type of heater became possible.

Instead of wrapping resistance wire around a thin sheet of mica, a piece of sheet metal properly slotted, as shown in Fig. 6, can take its place. Heaters of this kind are known as "Monoplane Heaters," and are still more efficient than the wire wrapped type, because the resistance offered to the passage of the heat in the insulating material is reduced considerably.

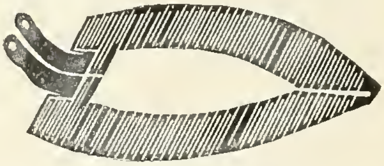

FIG. 6—SHEET METAL HEATING UNIT PLACED BETWEEN SHEET MICA

Another very efficient mica insulated heater is being obtained by painting on one side of a thin piece of mica a film of rare metal (platinum, gold), as shown in Fig. 7, the volatile oils of which, mixed with the metal powder, are removed by firing. The use of this type of heater, however, is limited, because it is difficult to produce a film of uniform section.

As mica dehydrates at about 800 degrees F., mica insulated heaters cannot be used for heating devices calling for temperatures higher than about 700 degrees. Since, however, a large majority of all heating appliances require lower temperatures than this, the mica insulated heater has come into general use during the last few years. It is preferred over the "embedded wire" heater, on account of its higher efficiency, its lower cost and the ease with which it can be replaced. Proof that this type of heater has reached a high grade of perfection is furnished by the fact that manufacturers are prepared to furnish guarantees for five years or more.

FIG. 7—METAL FILM HEATING UNIT PLACED BETWEEN SHEET MICA

The heaters so far described are not suitable for temperatures of more than 2 750 degrees. To obtain higher temperatures, carbon or graphite heaters are employed, as these materials, if prevented from oxidizing, will resist higher heats than any other metal known. Fig. 8 shows a section through a furnace with resistors of flat carbon plates *R*, one pile on each side of the furnace chamber. These carbons, being under pressure, are brought to a white incandescence by the electric current and radiate heat to the charge in the furnace. The construction of the entire device is such that the air has practically no admission, and whatever small amount may be in the furnace when starting, is driven out by the gases which develop the moment the current is turned on. Nevertheless, the carbon pieces have not a very long life. In these furnaces temperatures as high as 3 600 degrees F. can be produced.

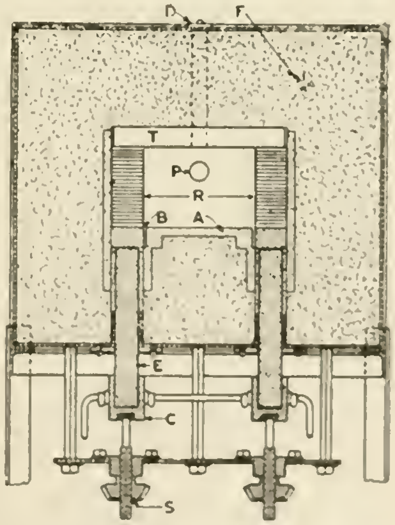

FIG. 8—CARBON-PLATE HEATING UNITS INSIDE OF A FURNACE

Another type of furnace is equipped with graphite heating units, which are protected from oxidization by working in a vacuum. It is claimed that with this construction temperatures as high as 5 500 degrees F. can be obtained.

Besides graphite and carbon, there are some refractory materials which are capable of withstanding high heat and which, at the same time, are good resistors. For instance, compressed metallic powder mixed with clay, silundum or kryptol.

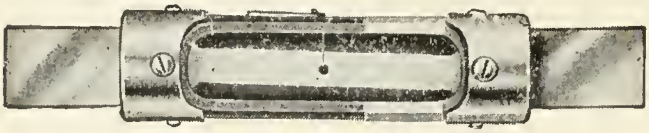

FIG. 9—ENCLOSED FUSE

Another type of heater, although ordinarily not classified as such, is the electric fuse, such as shown in Fig. 9. It consists of a piece of metal, usually wire or ribbon, the section of which is so calculated that the metal will heat, but not melt when carrying the amount of current for which it is designed. If for any reason the current exceeds this rated amount, then the increased heat in the fuse will melt the wire or ribbon and interrupt the circuit. Not only will fuses be found as safety devices wherever electricity is being used, but they are also applied for firing the charges in blasting. In the latter case, however, the fuse wire is so dimensioned, that it will glow or melt, igniting the charge the moment the electric current passes through the circuit.

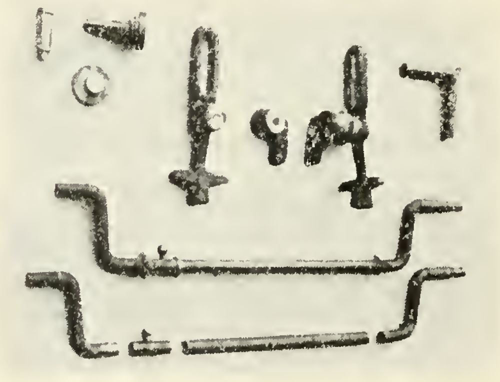

FIG. 10—SAMPLES OF ELECTRICALLY WELDED PARTS*

The joulean effect is also employed in electric welding. The principle involved is that of causing the electric current to pass through the parts of the metal to be welded, thereby generating heat at the point of contact, while at the same time pressure is applied to force the parts together. The moment the welding temperature is reached, the pressure follows up the softening surfaces, until a complete weld is effected. No special heater is required to perform this work. The art consists in applying at the right time the proper amount of current and pressure, both of which naturally vary considerably for different purposes. Fig. 10 shows a number of pieces before and after welding, but hardly does justice to the enormous possibilities in actual practice. Electric welding is not only replacing other methods of welding, but is also being adopted instead of riveting and other methods of joining parts, due to lower cost and superior work.

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*See article by Mr. C. B. Auel, on Incandescent Welding, in the JOURNAL for June, 1910, p. 430.

The Induction Type Heater, suitable only for alternating current, is another method of employing the joulean effect in a very effective manner. It consists of a transformer, the primary winding of which is connected to the electric current supply. The secondary is formed by a single or a few turns. Fig. 11 shows a vessel with a double wall. The inner and the outer shell, *1* and *2*, are concentric wrought iron cylinders and act on the secondary of the transformer. Space *3* between the shells contains the primary winding 5, which connects with the supply wire terminals *7*. The current, passing through the primary, magnetizes the wrought iron shells and induces an electric current sufficient to heat the shells. By selecting the proper proportions, heat of almost any desired temperature can be obtained. Vessels of this kind can be used for any process requiring heat, such as cooking, baking or heating liquids, melting metals, etc. The primary coil also can be so dimensioned that the heat generated in the secondary winding is so large that the metal forming the secondary will melt. This principle is used in a number of induction furnaces for obtaining metal directly from ore or for manufacturing fine grades of steel.

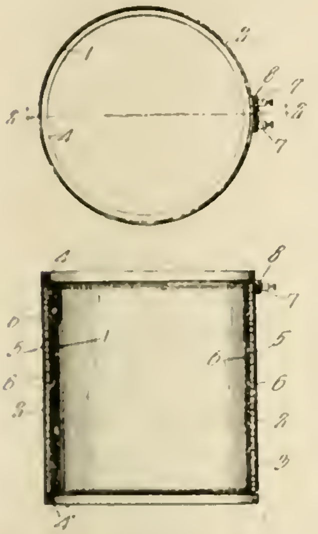


FIG. 11—INDUCTION TYPE OF HEATER APPLIED TO A TANK

Another interesting application of the induction type heater can be found in the electrical thawing of frozen water in pipes. The outfit consists of a transformer, the primray of which is connected to the electric service wires near the place where the thawing is to take place. The pipe with the frozen water is then connected in circuit with the secondary winding of the transformer and the heat generated by the current in the walls of the pipe is sufficient to melt the ice.

THE ELECTRIC ARC

When an electric arc is formed in air between carbon electrodes, their temperature is about 6 500 degrees F., at which point carbon volatilizes. The temperature of the gases in the arc is perhaps 1 500 degrees higher. To utilize this heat, in most cases, the arc is enclosed in a chamber formed by heat insulating materials. A furnace of this kind differs radically from any combustion furnace, as there are no products of combustion to carry off a large amount of the heat of the arc, and there is no cold air entering the chamber, chilling the entire furnace. With the exception of a small amount of heat passing through the walls of the furnace by conduction and radiation, there is no loss, and for this reason the electric arc furnace possesses a considerably higher efficiency than the combustion furnace. Fig. 12 illustrates how the electric arc is utilized in practice. *D* represents one electrode, *h* and *h* the other electrodes, and *g* and *c* the material which is to be heated and melted. The current entering at *D* forms an arc at the end of *D* passing over to *C*, and from *C* to *g*, leaving the furnace at *h*. In this case there is only *one* electrode for the current to enter but *two* or *more* electrodes for the current to pass out, in order to distribute it over the entire charge of the furnace as uniformly as possible and not concentrate the entire heat generated in a few points. The entire arrangement is enclosed in a housing, carefully lined with heat resisting material, in order to lose as little heat as possible by conduction and radiation.

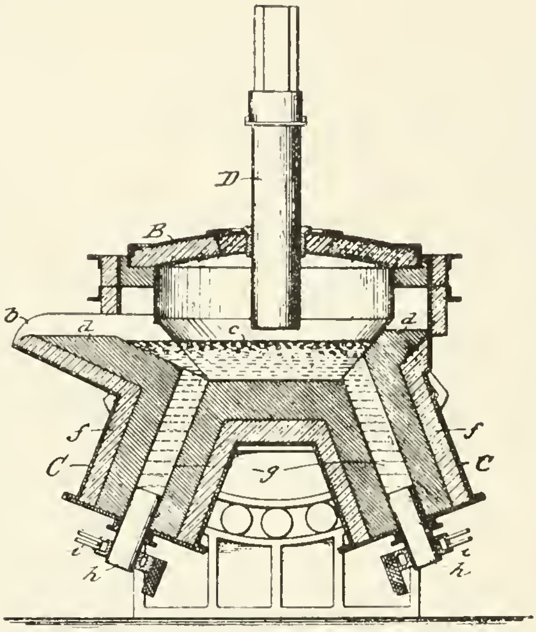


FIG. 12—SECTION THROUGH AN ELECTRIC ARC FURNACE

For different purposes, different constructions are found, which may be divided into direct and indirect arc furnaces. In the former, the charge is directly exposed to the arc, in the latter it receives the heat of the arc by reflection from the walls of the chamber. In both kinds, the electrodes may be arranged either in a vertical, horizontal or an inclined position. Commercial products of the electric arc furnace are artificial graphite, carborundum, artificial, emery, alundum, silundum, calcium carbide, aluminus-alloys, iron, steel, ferro-alloys and numerous others.

The heat of the electric arc, while mostly utilized in furnaces, can also be used very advantageously for cutting structural steel or for welding broken parts.

THE ELECTRIC SPARK

An electric spark, established between two metal terminals, produces sufficient heat to ignite inflammable materials in solid, liquid or gaseous state. Fig. 13 shows a section of a spark plug, containing two terminals about 1/16 in. apart and insulated from each other. In this case one of the terminals is grounded with the metal body, simplifying the construction materially. Spark gap plugs, such as illustrated in Fig. 13, are used in practically all internal combustion engines and similar devices based on the same principle are employed for gas lighters and for lighting blasting charges.

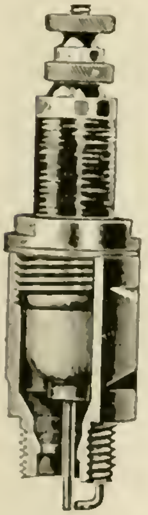


FIG. 13 — ELECTRIC SPARK PLUG FOR GAS ENGINE

Very little has been said about the methods of applying the various types of heaters to the objects, which are to be supplied with heat. Space is too limited to go into this problem in detail, but it may be stated that each individual case requires a careful study and that the large majority of all the troubles with electrical heating appliances has been caused by improper distribution of the heat and by imperfect construction of the connections with the electric current supply. High efficiency of course is most desirable, but a heater permitting a substantial, indestructible construction, the shape of which adopts itself without difficulty to the object which is to be heated, should always receive preference in the interest of durability.

A POST-GRADUATE CLUB

R. SEYBOLD

AFTER graduation a young engineer must take his place as a beginner in practical engineering work where he must rely on his own initiative for recognition and in further carrying on his education. From childhood until graduation the life of the average student follows along fairly definite lines. He spends nine months of each year under the direction of instructors, and acquires certain habits of thought and action. He becomes accustomed to receiving information without especial effort on his part, and he follows a certain type of social life among his fellow students.

In many cases the transition stage from the class room to the shop or office is a difficult one, and it often takes considerable time for the young engineer to become acclimated to his new surroundings and changed conditions. Many realize that they must begin to commercialize their education and that the better the conditions they can secure during this change-over stage the more quickly they can get into positions of responsibility; and thus we find them entering one or the other of the engineering student courses provided by various manufacturing concerns and large operating companies. During this period of re-adjustment the student who takes up industrial work with some one of the electrical organizations, must acquire an entirely new attitude, as well as experience, before he is of much value to his employer. On beginning such a course the student finds his days busily occupied in learning the details of the new work, but he is liable to have difficulty in feeling at home in the new surroundings after working hours and on holidays. In Pittsburgh this difficulty has been solved among the employees of the Westinghouse interests by a club made up largely of graduate engineers. It is the purpose of this club to furnish associations and surroundings similar to those in college and at the same time bring the young men in close touch with the more experienced engineers and officials of the different companies.

The club was organized in 1902 as "The Electric Club," with a membership of 150. In May, 1910, new and more spacious quarters were acquired, and the activities were greatly enlarged. As the membership included the employees of several of the Westinghouse Companies, the name was changed to "The Westinghouse Club."

The present quarters consist of a large auditorium, library, reception hall, general club room, pool room, writing room, several small meeting rooms, offices and a well equipped gymnasium. The walls of the various rooms are decorated with pennants, pictures and seals of the different colleges represented in the membership, as well as with illustrations of various types of apparatus. In the library are technical and popular magazines, and daily newspapers from various parts of the country. The Club has grown in the past three years until it is recognized not only as one of the important features in the welfare work of the different companies interested, but also as one of the leading organizations in the vicinity, socially, educationally and physically. The membership includes college graduates from all over the world. At present one hundred and sixty colleges are represented and there have been approximately 1 800 engineering students affiliated with the Club since its organization. One can hardly conceive of a better opportunity than this for the young engineer to become acquainted with those men whom he should know in his future career.

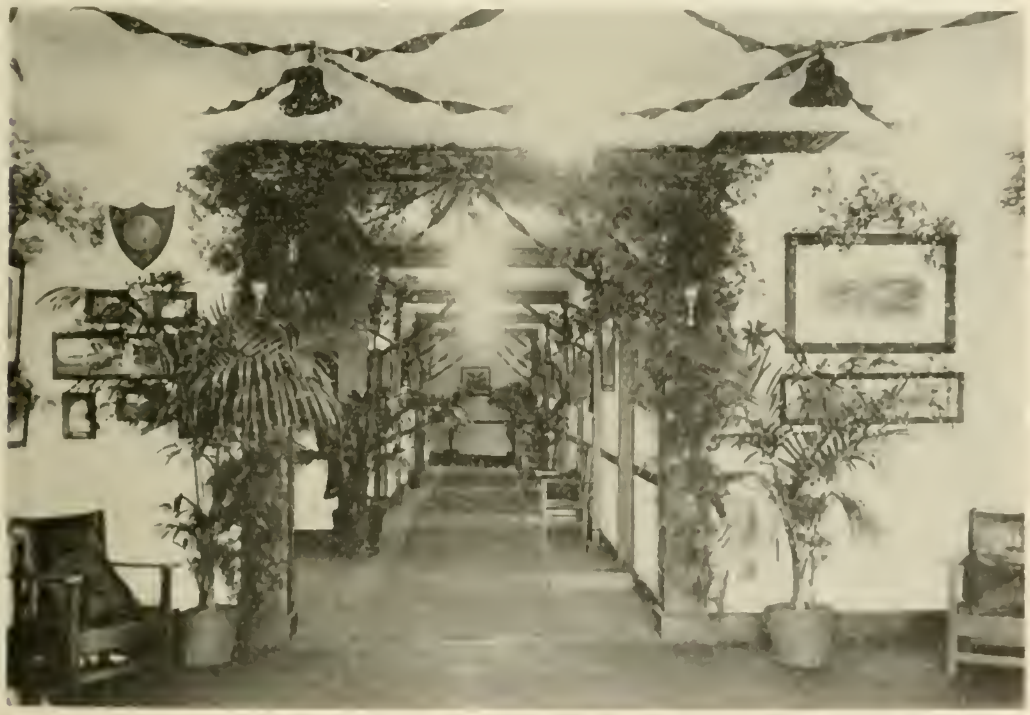


FIG. 1—VIEW OF MAIN CORRIDOR OF WESTINGHOUSE CLUB FROM THE RECEPTION HALL

The educational work of the club is divided into several distinct branches, such as popular and shop lectures, engineering excursions and technical sections. Popular lectures afford a chance for members and their friends to hear distinguished speakers on topics of interest to the general public, and the engineering lectures give the members an insight into the work being carried on in those branches of engineering with which they are not intimately acquainted. The technical section work is the predominate factor of the club. These sections are engineering classes, organized to deal with the theory, construction and application of various pieces of apparatus, or to consider other matters of importance in industrial organizations and works management. This course continues the college work and is carried on under the direction of instructors who have made a special study of the apparatus or work in question.

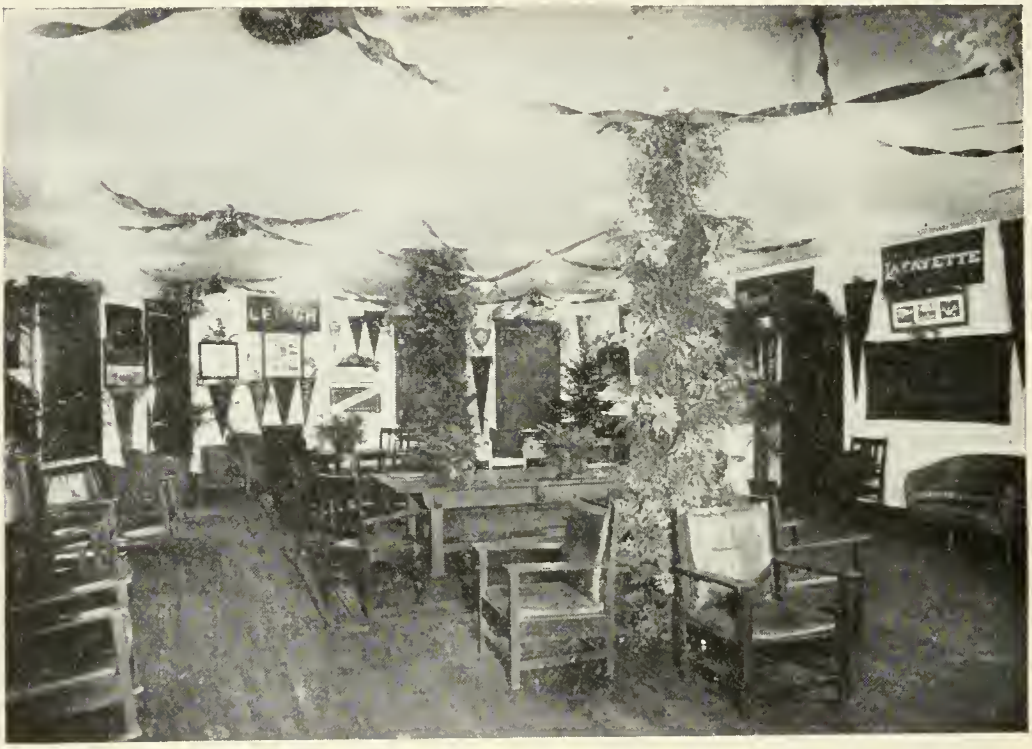


FIG. 2—THE PENNANT ROOM

Greater Pittsburgh is noted for the number and variety of its manufacturing and industrial plants. The Club has not overlooked these advantages, but maintains a special excursion committee, whose duty it is to arrange trips to the various plants on holidays, evenings and Saturday afternoons. Among the plants visited are the following: Edgar Thompson Steel Works, Power Plant of the Pittsburgh Railways Company, the Pressed Steel Car Company, Universal Portland Cement Company, Standard Underground Cable Company, National Tube Company, Bell Telephone Company, United Engineering & Foundry Company, American Steel & Wire Company, the Allegheny County Light Co., the Homestead Steel Works, the McClintock-Marshall Construction Co., the City Filtration Plant, and various others, including several electrically-operated coal mines.

The social features appeal especially to the young man just out of college. Dances and smokers are of frequent occurrence and musicals are given during each year by the orchestra, mandolin and glee clubs, with the idea of furnishing entertainment similar to that found in colleges.

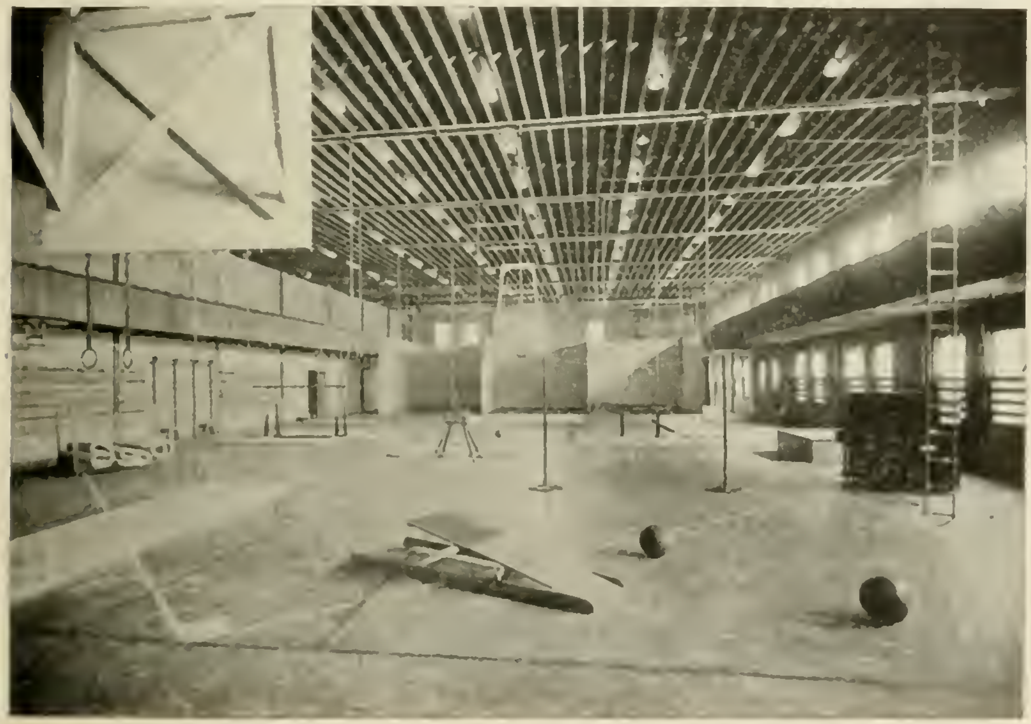


FIG. 3—THE GYMNASIUM

One of the principal features in all welfare work is the physical development. The Club activities are carried on under the direct supervision of an experienced physical director, who looks after individual instruction, as well as the various athletic teams. The gymnasium floor is 65 by 140 feet and the equipment includes the latest types of apparatus for class and exhibition purposes, including a 10 lap running track. The large membership of college men provides a group of trained athletes seldom found in such an organization. Teams are supported in basket ball, base ball, track and tennis. A very successful basket ball season has just closed, in which a schedule seldom equaled by any college team was carried out. This was made possible on account of the number of colleges located in and near Pittsburgh, or which visit Pittsburgh on trips, and, since many members of the Club teams are old college players, games are readily arranged. The track team contests with different college teams and participates in various Y. M. C. A. meets. The Club is one of the charter members of the Allegheny County Tennis Association, matches being played with some of the best Tennis teams in the country.

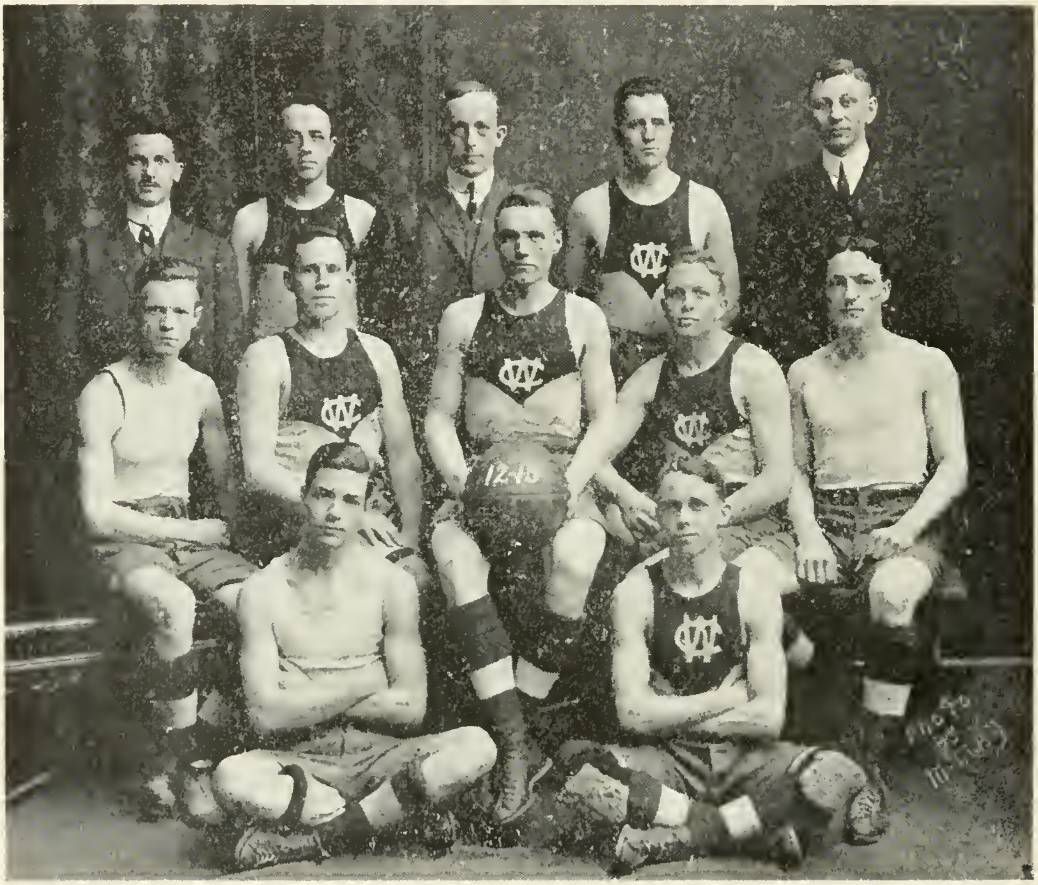


FIG. 4—BASKETBALL TEAM—1912-13

All of these various activities of the Club assist in making the life of the young engineer coming to Pittsburgh pleasant, and furnish social, educational and physical advantages which are of great assistance in developing him for a successful career in his profession.

SWITCHBOARDS FOR ALTERNATING-CURRENT POWER STATIONS-IV

C. H. SANDERSON

REMOTE MECHANICALLY CONTROLLED SWITCHBOARDS--Cont.

THE choice of the proper form of structure for the apparatus which is to be remote controlled and the satisfactory arrangement of the apparatus thereon presents a more difficult problem than does the design and arrangement of the panels themselves. The reason lies in the many practical forms of structure, and the large number of arrangements of the apparatus which may be made upon each of the various forms. For example, there are, first, the single-throw and double-throw systems. Under each of these the following arrangements are commonly employed:—

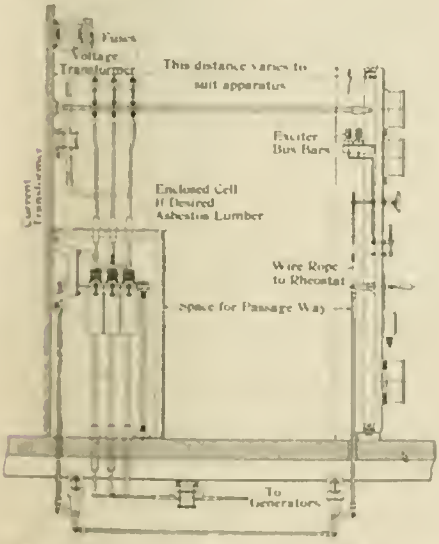


FIG. 1—WALL MOUNTING ARRANGEMENT FOR UN-ENCLOSED CIRCUIT BREAKERS AND BUS-BARS

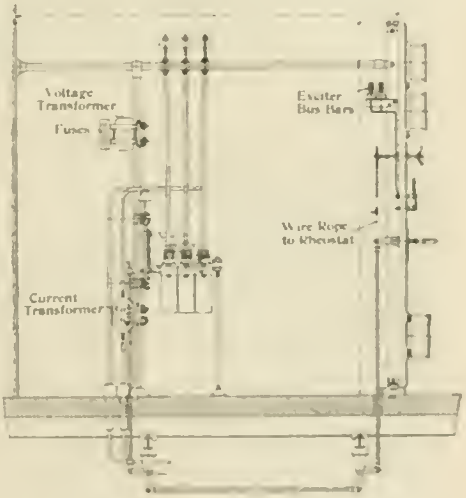


FIG. 2—SEPARATE MOUNTING ARRANGEMENT WITH BRACE TO WALL

1—*Wall Mounting*—All apparatus and bus-bars either mounted directly on, or supported from a wall of the building (Fig. 1).

2—*Framework Mounting*—All apparatus and bus-bars mounted on a framework of iron pipe or structural steel shapes, or a combination of the two (Figs. 2 and 3).

3—*Combination Wall and Framework Mounting*—As illustrated by Figs. 4, 5 and 6.

4—*Concrete or Masonry Structure Mounting*—All apparatus and bus-bars mounted in cells or compartments, as shown in Figs. 7, 8 and 10.

5—*Combination Concrete and Structural Mounting*—Circuit breakers in concrete, cells, remaining apparatus on iron framework, Fig. 9.

Many modifications of these arrangements are made as the conditions and surroundings warrant. Cells of asbestos lumber, slate, soap-stone, moulded concrete or other suitable material are frequently used to enclose all or a part of the circuit breaker where schemes *1* or *2* are employed. The remote control structure may be divided into two parts; the circuit breakers, for example, being mounted on the switchboard room floor with the bus-bars and auxiliary apparatus mounted in the room beneath.

CHOICE OF ARRANGEMENT

The following apparatus must usually be considered in choosing a satisfactory arrangement:—Circuit breakers, bus-bars and connections, rheostats, instrument transformers, fuses for potential transformer primaries and for main wiring when employed, and disconnecting switches. Before a proper choice can be made, a complete diagram, including all main wiring and all of the above apparatus should be carefully made, according to the system of connections which has been adopted for the installation under con-

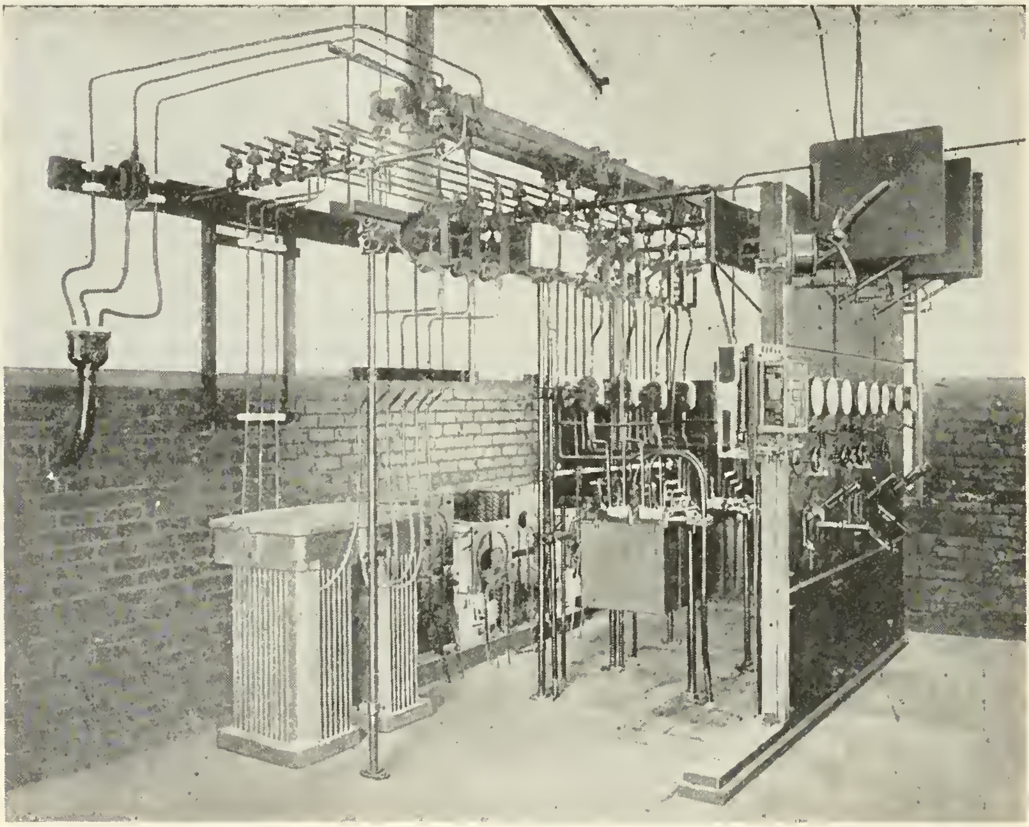


FIG. 3—A MOTOR-GENERATOR SUB-STATION SWITCHING EQUIPMENT FOR 1 500 VOLT DIRECT-CURRENT RAILWAY

Showing arrangement of starting and main alternating current bus bars (Piedmont Traction Co.), and assembly of all disconnecting switches and instrument transformers on the tubular framework. The control for rheostats, as well as circuit breakers, is taken beneath a section of removable flooring. The direct-current circuit breakers are also remote controlled from the middle section of the board, the switches being mounted on separate bases at the rear, near the top of the board.

sideration. From this wiring diagram should be selected the circuit which presents the most complications; that is, the greatest number of disconnecting switches, instrument transformers, etc., and, with the various practical forms of structure in mind, an arrangement should be worked out for this unit of the structure. If the remaining circuits have the same, or a less number of members in the same relative location in the circuits as regards the oil circuit breakers, the problem is solved and the remainder of the work is simply duplication. If the members in some circuits appear in other locations than those in the circuit chosen, each differing unit must be worked out individually, with a view, however, of forming them into a symmetrical and uniform structure. The choice of arrangement depends upon the capacity of the station, the cost, the available space, the voltage, the type of circuit breaker chosen and the current capacity of individual circuits.

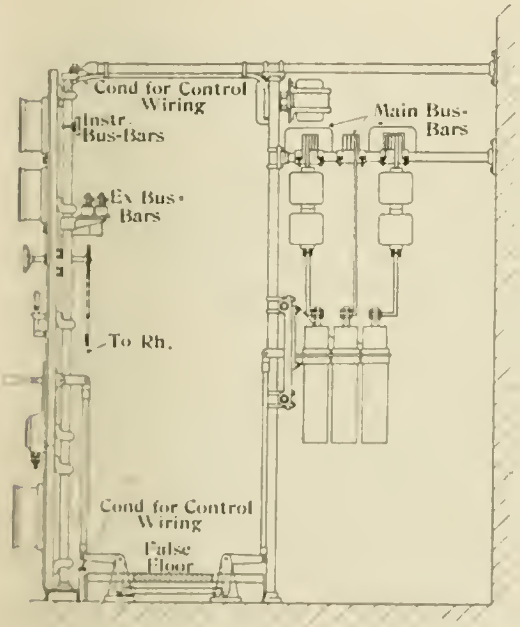


FIG. 4—COMBINATION WALL AND FRAMEWORK MOUNTED STRUCTURE

For heavy current capacity at low voltage. Similar to arrangement shown in Fig. 6. Inexpensive arrangement of control mechanism. Space back of board entirely free from main current carrying parts.

DISCUSSION

The capacity of the station, that is, the entire amount of energy which can be concentrated on the bus-bars, decides the capacity of circuit breaker to be used and the capacity and design of the bus-bars, connections and auxiliary apparatus. The comparative costs of the various arrangements are indicated approximately in Table I, the costs given covering in each case, all framework, (two uprights) or concrete, and mountings for one three-pole circuit breaker with instrument transformers, etc., and with remote control mechanism; in other words, all material which must be added to the self-contained type of board to make it remote controlled.

It should be remembered that wall arrangements such as shown in Fig. 1 may be more costly than the separate arrangement shown in Fig. 2, if large windows, which must be bridged by steel work, occur back of the board. Concrete or masonry structures may add considerable to the cost of floor construction and support on account of their great weight. The wall mounting arrangements, shown in Figs. 1 and 8 occupy the least space but have the disadvantage of giving accessibility from one side only. For this reason and because of the great increase in available space for mounting various members of the assembly, the separate mounted structures are preferred where space can be found. Fig. 4 shows approximately the minimum space which is required for the average structure, while more generous space is provided in Fig. 2. All high tension connections and circuit breakers in Fig. 4 are on that side of the supporting framework away from the switchboard, and the remote control mechanism is of minimum length and weight. Moreover, if desired, a metal screen may be placed along

TABLE I

Wall mounting (Fig. 1) including I-beam supports for remote control mechanism	$ 8.00	
Separate mounting (Fig. 2) including I-beam supports for remote control mechanism	13.00	
Combination wall and separate mounting (Fig. 4), including slate false flooring over mechanism	10.50	
Combination pipe and concrete structure (Fig. 9)	35.00 to	$ 40.00
Wall supported concrete structure (Fig. 8)	75.00 to	100.00
Separate concrete structure (Fig. 7)	75.00 to	100.00

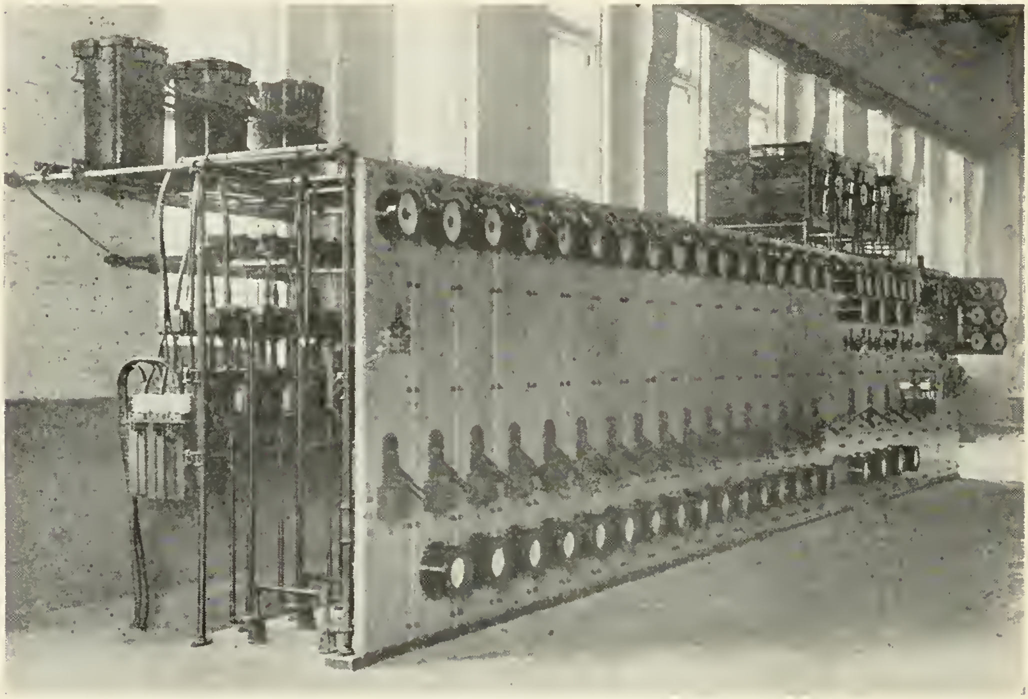


FIG. 5—LARGE REMOTE-CONTROLLED SWITCHBOARD

With apparatus arranged similar to Fig. 4. Rheostats mounted in view of operator above the board. (Marathon Paper Company.)

the structural uprights, entirely separating the low tension wiring and details on the back of the board from the high tension apparatus, thus insuring the safety of attendants when working at the back of the switchboard.

The voltage of the system determines the spacing of the various members of the arrangement and influences the size and type of the circuit breaker chosen. Moreover, it has certain influence on the arrangement in that concrete or masonry structures are not recommended for voltages above 13 200 volts. This recommendation is due to the fact that for higher voltages, concrete or masonry structures must be considered as "dead ground" and therefore, since the tendency toward leakage and corona increases as the voltage increases, safe spacing distances would necessitate a very large and expensive structure.

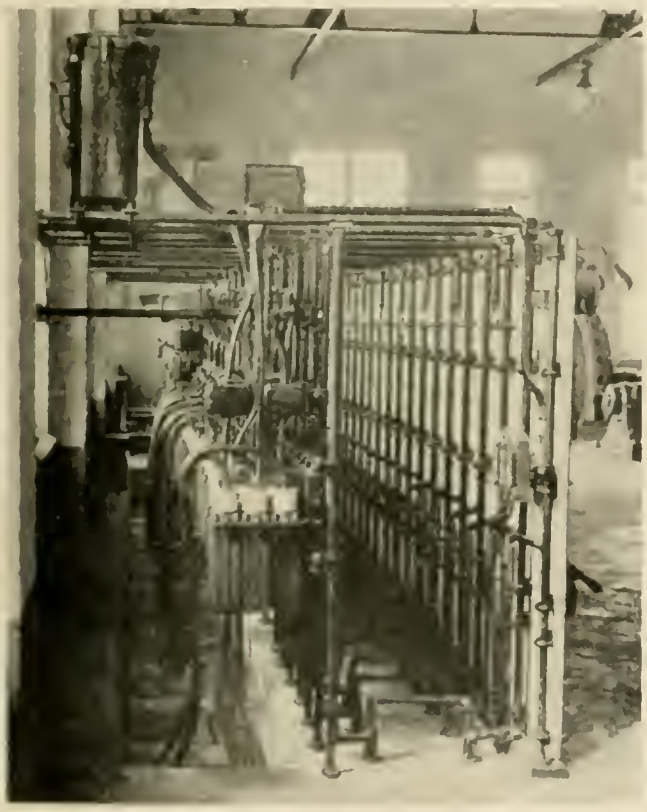


FIG. 6—END VIEW OF REMOTE-CONTROLLED SWITCHBOARD SHOWN IN FIG. 5

False flooring over control mechanism not shown.

There are two kinds of circuit breakers as regards their mounting; those designed for wall or pipe frame mounting and those for cell mounting. Any of the former may be enclosed in cells if desired, as shown in Fig. 1. By the latter is meant those circuit breakers assembled from unit poles, each pole being designed to occupy a separate cell, as shown in Fig. 10.

The current capacity of the individual circuits determines the size of the circuit breaker, and the nature of the connections between circuit breaker and bus-bars; that is, whether solid wire, copper rod, cable or copper straps must be used. Moreover, the current capacity determines the type of current transformers. Those shown in Figs. 1 and 2 are for small current capacity and require special mounting, whereas those shown in Fig. 4, for large current capacity, are designed to slip over the laminated strap connections and do not require special support.

THE REMOTE CONTROL MECHANISM

The control mechanism which is used to the practical exclusion of all others for switches and circuit breakers consists of a series of levers and rods. The direction of the operating force is always linear, changes in direction being made by means of short levers rotating on a fixed fulcrum, commonly known as "bell cranks" (Figs. 11 and 12). A handwheel and rotating shaft, with bevel gears or universal joints for changing direction of motion are used to a considerable extent by foreign manufacturers

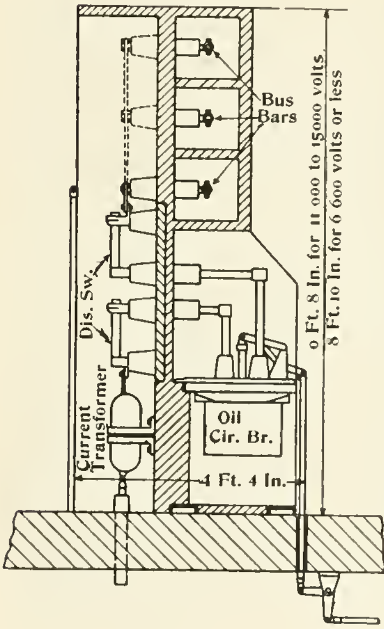

Bus
Bars
Dis. Sw.
Current Transformer
Oil Cir. Br.
4 Ft. 4 In.
9 Ft. 8 In. for 11 000 to 15000 volts
8 Ft. 10 In. for 6 600 volts or less

FIG. 7—CONCRETE OR MASONRY ENCLOSED SEPARATE MOUNTING STRUCTURE
Typical arrangement of apparatus and bus bars. 13 200 volt apparatus shown. Self-supporting and accessible from both sides. May be entirely enclosed by use of cell doors.

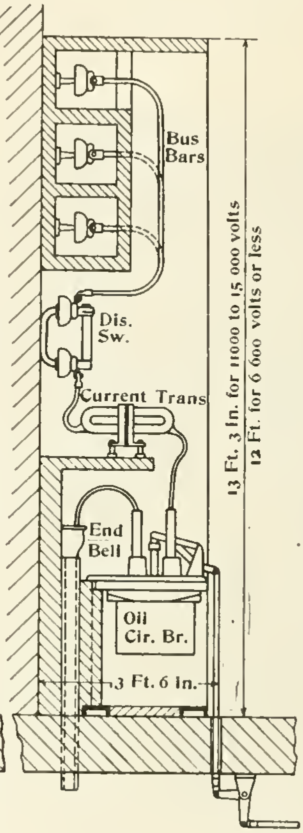

Bus
Bars
Dis.
Sw.
Current Trans
End
Bell
Oil Cir. Br.
3 Ft. 6 In.
13 Ft. 3 In. for 11000 to 15 000 volts
12 Ft. for 6 600 volts or less

FIG. 8—WALL MOUNTING CONCRETE OR MASONRY ENCLOSED STRUCTURE
13 200 volt apparatus shown. Requires but little space. Accessible from one side only. Provides space for but one set of disconnecting swithces.

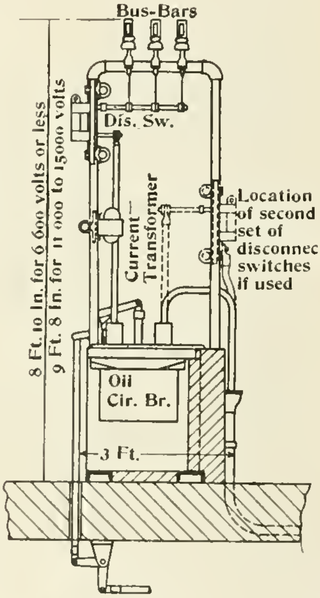

Bus-Bars
Dis. Sw.
Current Transformer
Location of second set of disconnecting switches if used
Oil Cir. Br.
3 Ft.
8 Ft. 10 In. for 6 600 volts or less
9 Ft. 8 In. for 11 000 to 15000 volts

FIG. 9—COMBINATION CONCRETE OR MASONRY AND PIPE FRAMEWORK STRUCTURE; SELF-SUPPORTING
Comparatively inexpensive construction, is of less width than arrangements of Figs. 7 and 8, but live parts are unprotected. 6 600 volt apparatus shown.

and to a small extent in this country. The use of one or the other is influenced to a certain extent by the design of the apparatus to be controlled, that is, whether the motion of its moving parts is linear or rotary. The first described mechanism is, however, much cheaper, as less expensive materials may be used and very little machine work is required. Moreover it lends itself more readily to the application of automatic action, especially where the latch and trip coils are located at the operating handle. The connecting rods (Figs. 11 and 12) are commonly made of three-fourths inch gas pipe, as it is cheap and usually easy to obtain, and is naturally well suited for the purpose. Wooden rods are sometimes used because of their light weight, and in some cases, such as for field switches or disconnecting switches, on account of their insulating properties.

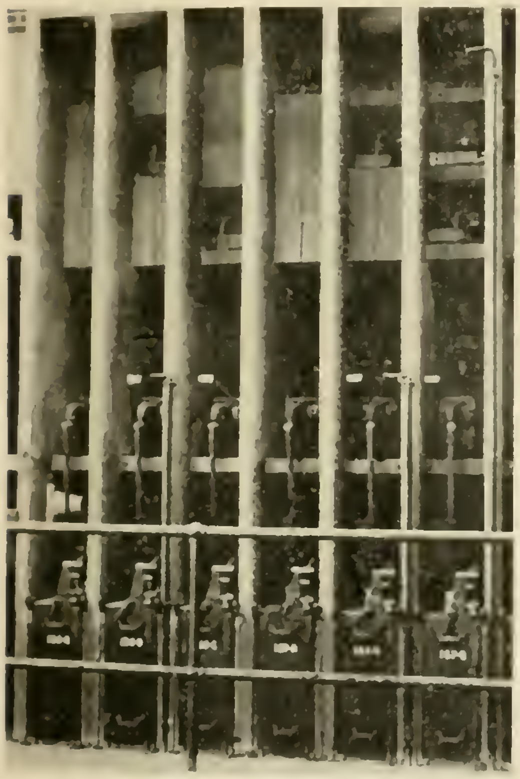


FIG. 10—OIL CIRCUIT BREAKER STRUCTURE CORRESPONDING TO FIG. 8
Showing front view of wall mounting structure. Two complete circuit breaker units shown. (Used by Development & Funding Company.)

Mechanisms for automatic circuit breakers are of two kinds; those in which the mechanism is stationary during automatic tripping of the circuit breaker, in which case the circuit breaker is said to trip free from the mechanism, (Fig. 12), and those in which the mechanism returns to the open position (Fig. 11) at the time of opening of the circuit. The latch and trip coils may be mounted at the circuit breaker for both kinds, but it is most usual with the latter kind to mount them at the operating handle. The arrangement of mounting the trip coils and latch at the control handle with the control mechanism and breaker both tripping free from the handle is the one most commonly used. The trip coils, or relays if used, are usually actuated by the same current transformers which operate the ammeter, and this arrangement permits all secondary wiring from the current transformers to be made at the switchboard. Moreover, as the auxiliary lever (Fig. 11) indicates the open or closed position of the circuit breaker, the operator does not require a signal device at the switchboard for this purpose. Where the distance from the switchboard to the circuit breaker is considerable, however, it is advisable to place the trip coils, latch, and relays, if used, at the circuit breaker so that the

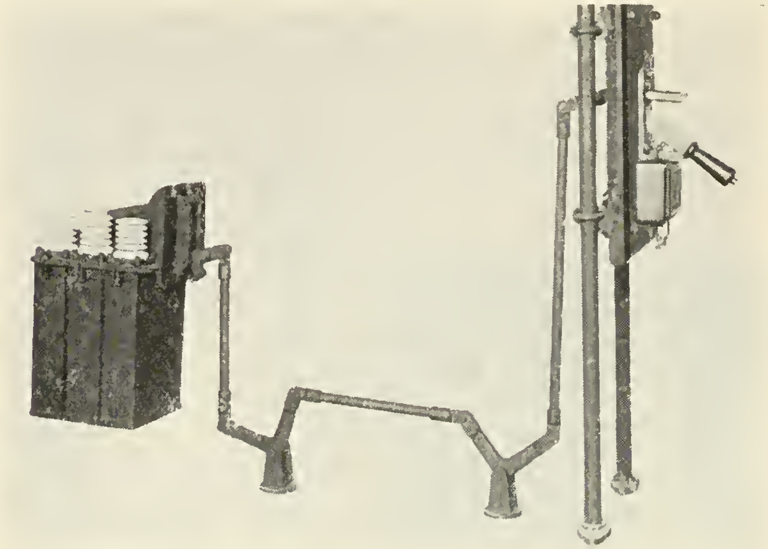


FIG. 11—REMOTE CONTROL MECHANISM WITH LATCH AND TRIP COILS AT THE HANDLE

Mechanism moves when oil circuit breaker opens, the auxiliary handle lever tripping free from the handle while the main handle lever remains in lower position. Mechanism shown just after tripping.

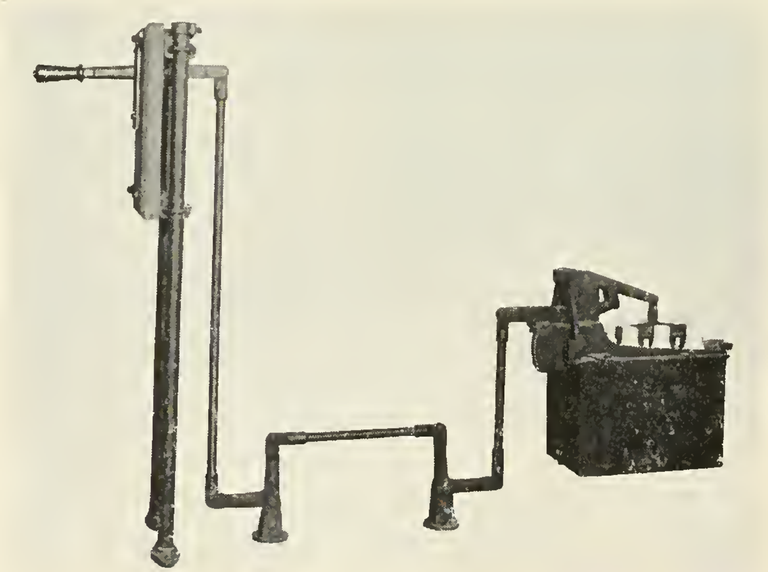


FIG. 12—REMOTE CONTROL MECHANISM WITH LATCH AND TRIP COILS AT THE CIRCUIT BREAKER

The mechanism does not move when breaker opens automatically. Automatic action of the breaker is indicated at the board by some form of signal device.

the latter will trip free from the heavy mechanism. In this case an indicating device at the switchboard, such as a lamp or mechanical signal, is desirable even though the instruments may indicate, to a certain extent, the condition of the circuit. A long heavy mechanism will considerably increase the inertia of the moving element and consequently slow down the action of the circuit breaker. If, therefore, this form of mechanism must be used, an accelerating device, such as a spring, combined with a dash-pot to absorb the shock of opening, should be applied to regain the inherent speed of the breaker. A heavy, stiff spring is often introduced into the mechanism where the tripping mechanism is at the switchboard panel, to give a greater degree of flexibility, insuring a good, dependable pressure on the contacts.

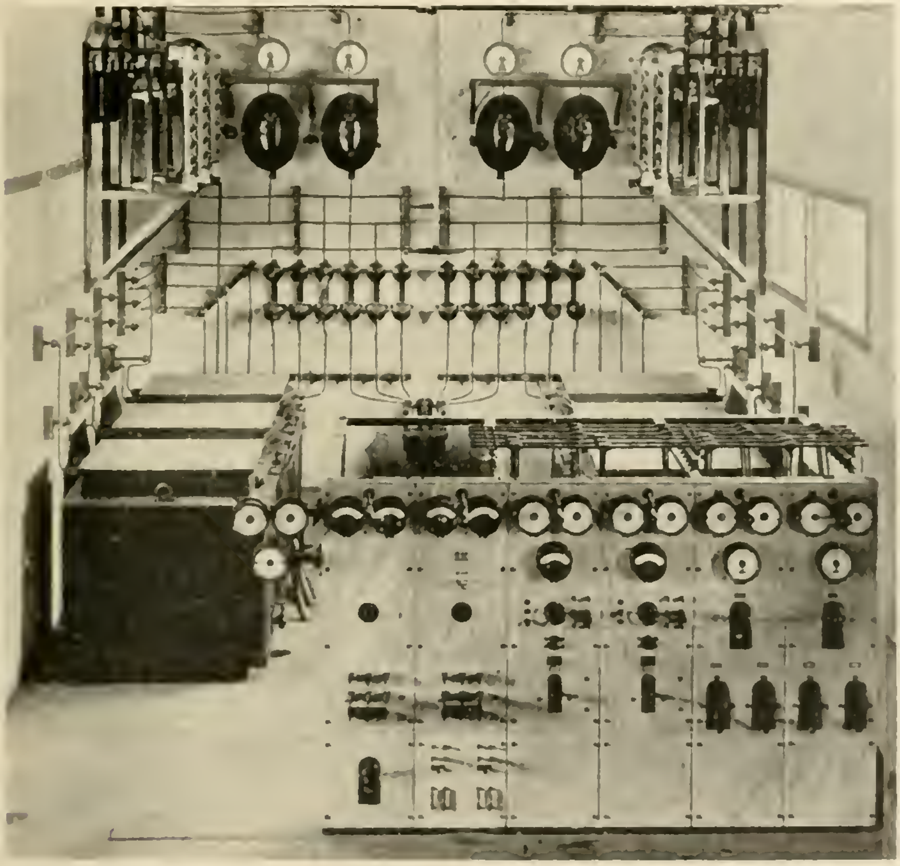


FIG. 13 SUB-STATION ARRANGEMENT OF SWITCHBOARD
Including remote control high tension breaker, bus-bars, transformers, lightning arresters, choke coils and disconnecting switches

Most mechanisms have considerable flexibility, however, owing to the manner in which they are supported, and therefore the spring need not be used except on short rigid runs of mechanisms and where the connection is made direct to the circuit breaker without the use of bell cranks.

SHOP TESTING OF ELECTRICAL APPARATUS

IV—GENERAL TESTS OF DIRECT-CURRENT MACHINES

BEFORE starting a test run on any new apparatus a careful mechanical inspection should be made. The bearings should be examined to make certain that the oil is at the proper height in the gauges; the air-gap must be uniform and free from obstructions, and all pulleys securely fastened to their shafts.

SETTING OF BRUSHES AND BRUSH-HOLDERS

The position of the brushes and brush-holders of direct-current machines demands careful attention. The brushes should make the specified angle with the commutator, and run with or against it, according to the requirements of each particular case. The lower edges of the brush-holders should be about one-eighth inch from the surface of the commutator. The brush arms must be equally spaced around the commutator. In order to check the spacing, a narrow strip of paper or ticker tape should be wrapped around the commutator under the brushes, care being taken that it is parallel to the edge of the commutator. A mark is made on the paper along the front, or toe, of each row of brushes, as well as a number to identify the brushes. The paper is then removed and the distance between the marks measured. If these distances are not equal, the brush arms or holders should be adjusted till the spacing is correct; the variation should not exceed one-sixteenth of an inch, and for commutating-pole machines one-thirty-second of an inch.

The carbon-holder springs should be adjusted so that the pressure on all brushes is uniform. The degree of tension desirable varies to some extent, depending on the size and speed of the machine and the service to which it is subjected. Carbons running on slip rings will maintain good contact with one and one-half pounds pressure per brush; those running on railway motor commutators need from four to five pounds; two to two and one-half pounds is perhaps a fair value in the case of the average machine. In general the tension should be as light as possible and yet maintain proper contact with the commutator at all times. Carbons should be carefully sand-papered so that the entire face of the brush is in contact with the commutator. The paper should be gripped by the edges and held firmly against the surface of the commutator during the grinding, special care being taken that the edges of the brushes are not rounded off. On the finishing strokes the grinding should be done with fine sand-paper, and only in the direction of rotation, the brush being lifted for the return stroke. If this operation is carefully performed the brushes should polish up to a perfect surface after a few hours running. However, in some cases it may be necessary to run certain brushes for several hours under heavy tension to obtain the proper contact.

COMMUTATOR

The commutator, to be in good operating condition, should run true and have a smooth polished surface free from high bars, high mica, or any other unevenness. It should remain in this condition indefinitely unless injured by excessive heating or sparking due to abnormal operating conditions. Commutators are commonly subjected to a seasoning process by the manufacturer, consisting in alternately heating and tightening the commutator until all volatile substances in the mica bond have been driven off and the bars themselves have become permanently seated. The smaller commutators are seasoned by gas heat during the building process, but the larger sizes are, in addition, seasoned electrically after the machines are complete. In the electrical process, the heating effect is obtained by short-circuiting the terminals and exciting the field so that a heavy current will flow through the commutator bars. The amount of excitation required will be small. In commutating-pole machines the commutating winding should be left in series with the armature on short-circuit. This will permit a much higher current to circulate before the point of injurious sparking is reached.

In starting the machine, care must be taken that the brushes are on the neutral position; otherwise the machine may build up a dangerous current as a series generator. To prevent damage from this source, a circuit-breaker should be in series with the armature and commutating poles. With this connection the separate excitation of the shunt field will probably not be required, the current being controlled by shifting the brushes very slightly away from neutral. The tension on the brushes should be high, so that their friction will increase the heating effect. A spare set of carbons should be used in this test as the rough commutator and sparking will probably injure a regular set. In order that any minor defects may become more pronounced, commutators should be run at 20 percent over-speed during the seasoning process. If any of the bars show a tendency to rise, the "V" rings should be tightened while the machine is still hot. It may be necessary to repeat the heating process several times before the bars are firmly seated. The commutator should then be turned down or ground until it is in good condition. A good polish may be obtained by running several hours with hard brushes under heavy tension, occasionally oiling the commutator sparingly with heavy cylinder oil.

Commutation—Whether the commutation characteristics of a machine are good or bad is indicated by the degree of sparking at the commutator. A well designed machine in good condition should show no sparking when run at full load, and its commutator should tend to polish and not blacken or burn.

POLARITY TESTS

There are three classes of polarity tests: 1—Those to determine the relative polarity of the field poles; 2—Those to determine whether the series and shunt coils on the same pole are correctly wound and connected; 3—Tests on commutating-poles.

A simple method of checking the polarity of adjacent field-poles is to excite the coils and try the magnetic pull between each two poles by means of an iron bar. Should there be a reversed coil on any pole, the fact will be indicated by a greatly decreased pull on the bar when held between that pole and those adjacent. For large machines having series fields this method is not satisfactory, as an excessive current is required to excite the poles sufficiently to detect the difference in pull. In such cases the use of a compass is resorted to, the compass being passed slowly around the poles in order. If the polarity is correct, the needle will reverse its position as it is moved from one pole to the next. For this test, a very weak current should be used to excite the poles, as otherwise the polarity of the compass may be changed and the value of the results destroyed. When a generator is being tested, it is often more convenient to run it under load and short-circuit each series coil in succession with a heavy jumper, watching the terminal voltage, which should decrease as each coil is cut out.

If it is not convenient to use any of the above methods in checking the relative polarity of shunt and series coils on a compound machine, the correctness of the field connections may be determined by starting the machine first as a compound motor, and then as a series motor, and noting the direction of rotation. For a generator or a differentially connected motor, the rotation should be in opposite directions, while for a motor of standard connection the direction of rotation should be the same for both conditions.

Commutating Poles—For generators, the commutating pole ahead of a main pole in the direction of rotation must be of the opposite polarity from that main pole, while for motors the commutating pole ahead of a main pole must be the same polarity as the main pole, as shown in Fig. 1.

POSITION OF BRUSHES

For every direct-current machine a position of the brushes may be found, such that the voltage generated in the coils short-circuited by the brushes will be a minimum. This is called the neutral position. For machines without commutating poles this position shifts with the load and the brushes should be shifted accordingly to obtain the best operating conditions. However, as this is not practicable in most cases, the brushes are commonly set in the best average position. All such positions are referred to as being so many bars ahead of no-load neutral for generators and back of no-load neutral for motors. In case of properly compensated commutating-pole machines the neutral does not shift with the load, the effect of the commutating-pole being to neutralize the shifting tendency. In such cases the brushes should always be left on the no-load neutral position. There are a number of methods of determining the position of this no-load neutral.

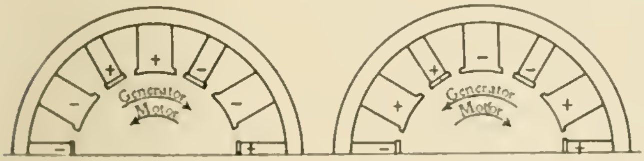


FIG. 1—RELATIVE POLARITY OF COMMUTATING AND MAIN POLES FOR GENERATORS AND MOTORS

Voltmeter Method—With the machine operating at normal voltage and no-load, two leads from a low reading voltmeter spaced the width of one commutator bar apart are held on the commutator. They are slowly moved around the commutator until a position of minimum reading is obtained, this being the no-load neutral. The same method is applicable for determining the correct brush position under any condition of load, and this determines the correct amount of lag or lead to give the brushes in a non-commutating-pole machine. This method is simple and is sufficiently accurate for any non-commutating pole machine, and is sometimes used for small commutating pole machines. For commutating-pole machines, however, a more accurate setting of the brushes than can be obtained by this method is usually required.

The "Kick Method," giving the so-called "Kick Neutral," is based on the fact that when the field circuit of any direct-current machine is opened, an induced voltage is generated in the armature windings. Before starting the test the brushes should be set as close as possible to the neutral position. This can be determined by setting an armature slot under the center of the commutating-pole and then moving the rocker ring until the brushes on one arm cover the commutator bars which are connected to the conductors in this slot. All the brushes should be removed, and a brush whose face has been bevelled to practically a knife-edge at the middle of the brush should be inserted in one brush-holder on each arm. The shunt field is separately excited and controlled by a quick break switch or circuit breaker. The kick on a voltmeter connected across brush arms of opposite polarity is observed when the field circuit is interrupted. A meter with a 0.5, 1.5 and 15-volt scale is to be preferred for this purpose, as it can readily be adapted to the deflection registered. If the brushes are in the exact neutral position, the voltages generated in the windings will neutralize each other and no deflection of the needle will be observed. If any deflection is noted, the rocker arm should be moved until the circuit in the main field may be either opened or closed without any kick being observed. It should then be clamped firmly in that position, chisel marks being made on both the rocker ring and the frame as a means of identification in case the ring should happen to be moved.

The "Running Neutral" Method is based on the principle that if the brushes are in the correct no-load neutral position, no active electromotive-force will be generated by the commutating-pole flux when the machine is running on open circuit, with the commutating windings separately excited. Pointed brushes are inserted, one in each arm, as in the "Kick Method," except that the edges of the brushes must be wide enough to cover the mica between the segments and to give a good even contact on the commutator. For accuracy this method requires that there be no residual magnetism in the main field. The machine is therefore brought up to approximately normal speed, and by exciting the machine, for an instant only, in a direction contrary to normal, it is demagnetized entirely; that is, until no deflection shows on the low scale of the voltmeter. Any deflection then obtained by exciting the commutating-poles will be due to the flux from these poles only and not to a combination of the two. The commutating-poles are then excited to about two percent of their normal current and the brushes shifted until no deflection is obtained on the low scale of the voltmeter. The residual magnetism must be checked from time to time, keeping it at as low a value as possible by proper excitation of the shunt field. After determining the best location for the brushes at this excitation, raise the commutating-pole current to about four percent of normal and check results. If no difference is found, reverse the current in the commutating-pole and try again, still checking the residual from time to time. In some cases higher currents may be used, but the leakage flux soon becomes large enough to destroy the symmetry of the normal field form and indefinite results will be obtained.

This method, if used carefully, gives very good results. The position of the brushes is at the peak of the commutating-pole field form, and as this peak is rather sharp, the effect of displacement will be marked. Since the machine is running, errors due to brush resistance or to a brush resting on mica only, are eliminated. It is to be preferred to the "kick method" in most cases, but either method should give the same result. If any discrepancy is found, the spacing of the poles or brush arms is in error and should be investigated before preceding further with the test. Both these methods show the resultant or average neutral position due to all the commutating-poles and brush arms, whereas by the voltmeter method slightly different locations may be found for each pole and brush arm and the average position must be taken.

The Running Position of the Brushes—Non-commutating pole machines that are to be operated at constant speed in one direction only should have the brushes set slightly off the neutral position, forward for generators and backward for motors. For machines under 100 kilowatts, this lead will ordinarily be about 1.5 percent of the total number of bars in the commutator. In larger sizes, as well as in special cases in the smaller sizes, the running position is determined by giving the brushes as large a lead as possible to obtain good commutation at no-load, but the brushes must not be moved farther than the full load neutral point as determined by the voltmeter method. For adjustable speed, non-commutating-pole motors, the lead at running position is approximately 0.75 percent of the total number of bars in the commutator. On all motors which are operated in both directions, the running position is the no-load neutral point.

The running position of the brushes of commutating-pole machines is the no-load neutral position as found, for large machines, by the methods previously described. In the case of small machines, such elaborate methods are not necessary and the neutral is checked by running the machine as a motor at its highest rated speed and normal load in both directions of rotation. The speeds obtained in either direction under the same conditions should check within two percent. When it is impossible to run the machine at its highest rated speed and load on account of instability, the rocker arm should be adjusted at the highest speed and load obtainable with stable conditions. In the case of small commutating-pole generators, the brush-holders should be so located that the machine will give the same regulation in both directions of rotation. In all tests for determining the correct position of the brushes by reversing the rotation of the machine under test, special care must be taken that the brushes fit their holders properly and that their faces have contact with the commutator at practically all points, irrespective of the direction of rotation. The difficulty in getting perfect brush contact may be overcome by using special narrow brushes which will give practically the same contact irrespective of the direction of rotation. The rocker arm position, when finally determined as above, should be marked.

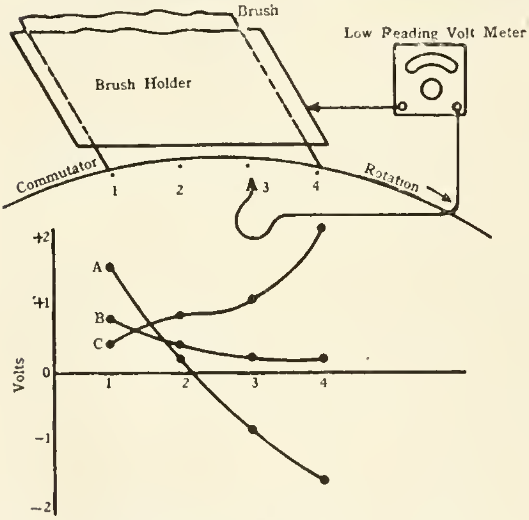


FIG. 2—METHOD OF MEASURING BRUSH POTENTIAL

Adjustment of Commutating Pole Field—The commutating fields of all motors and generators must be adjusted so that the current is distributed properly over the entire face of the brush, as shown by the potential from the brush to the commutator with the machine running at normal load and speed. The brush drop must be measured from the carbon holder to four equi-distant points,—heel, toe and two intermediate points on the commutator, directly under the brush. The heel of the brush is that edge which the commutator bars touch first when the machine is running in the proper direction of rotation. The readings of brush drop should be taken in the direction of rotation, i. e., from the heel to the toe. When the potential decreases from the heel to the toe, the commutating-pole field is too strong (over-compensated), and should be shunted, or the number of turns in the coils reduced (except as noted below). When the potential increases from the heel to the toe, the commutating-pole field is too weak (under-compensated). The foregoing conditions are illustrated in Fig. 2, in which curve *A* illustrates the first case, curve *C* the second, and curve *B* the correct condition. The field should be adjusted so that at normal load it will be slightly over-compensated, as this will take care of the saturation of the iron at the maximum overloads. When the commutating-pole field has been properly adjusted, the commutation up to 75 or 100 percent overload should still be good, except possibly for a slight glowing of the brushes.

Stability—The operation of all motors must be checked for stability. In the case of constant speed motors this test consists in throwing 200 percent load on and off with full field on the motor; also 125 percent load at 150 percent rated speed. This last test is taken at 10 percent above highest rated speed in the case of variable speed motors. In each case each test must be made in both directions of rotation. The machine is unstable if the speed of the machine increases greatly, or the ammeter reading is excessive or fluctuates widely, due to partial neutralization of the shunt field by the commutating field. In such cases the commutating-pole field should be shunted, or the shunt field strengthened by a few compensating turns in series with the armature.

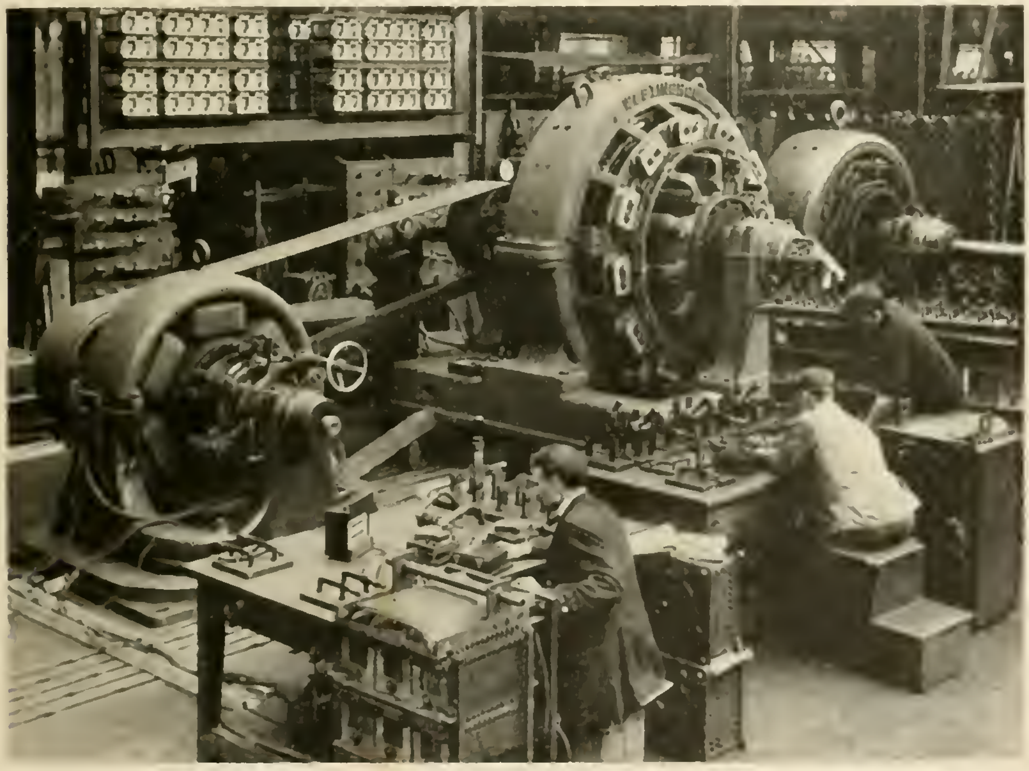


FIG. 3—IRON LOSS TEST OF A ROTARY CONVERTER SHOWING USE OF TEST TABLES

RESISTANCE

The cold resistance of the armature of any direct current machine may be taken by the bridge method with all the brushes on the commutator. These should be ground to a good fit, and be in normal operating condition. Current is circulated through the armature windings by connecting the current leads of the bridge to the brush-holders of two adjacent brush arms, the potential leads being held on the bars nearest the center of the brushes. If it is desired to take the resistance of the armature hot, the bars used should be marked with a center punch and the hot resistance taken between the same points and with the bars in the same location relative to the brushes. In the case of large direct-current machines it may not be convenient to turn the armature to conform to the above condition, so that it may be necessary to take a second cold resistance, this being taken in such a manner that it may readily be duplicated for the hot resistance irrespective of the position of the armature. The current in this case is introduced into the armature by holding or fastening the current leads directly on the commutator bars between which the drop is to be taken. These bars are selected a distance apart approximately equal to the throw of the coils, irrespective of the position of the brushes. The bars are marked as before with a center punch, two marks being made to distinguish this position from the first. The hot resistance is then taken across these same bars without reference to their location.

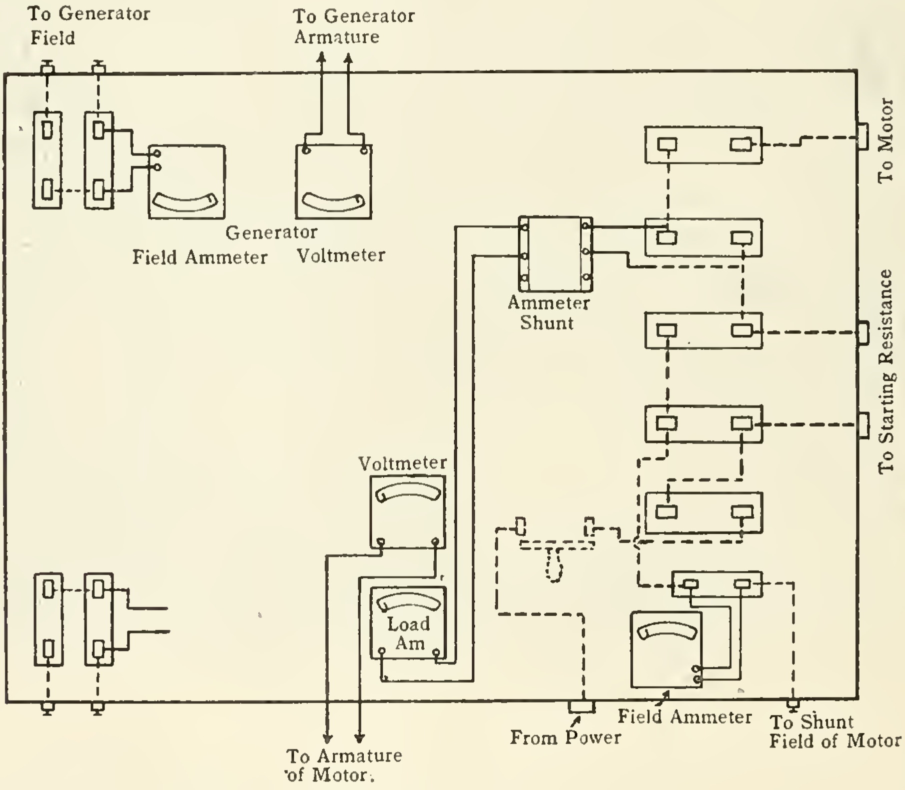


FIG. 4—DIAGRAM OF CONNECTIONS, TEST TABLE NO. I

Where many similar tests are to be made, conecting the various instruments and switches into the proper circuits is greatly facilitated by the use of a test table, permanently wired. The tables shown in Figs. 4 and 5, represents wiring schemes which have been found very convenient in testing direct-current machines.

The resistances of the series and commutating-field, being very low, are rather difficult to measure accurately without special apparatus. However, with proper care, fairly consistent results can be obtained with portable bridges of the Kelvin type; as high a current and as low a ratio as possible should be used. Where practicable, it is well to inspect the machine wiring before taking the resistance, making certain that there are no loose connections or bad contacts. The resistance of the shunt field may be taken both by the Wheatstone Bridge and the drop of potential method; the latter being used in connection with a similar measurement during the load tests, for the calculation of the rise by resistance.

FRICTION AND CORE LOSSES

The core loss of machines is ordinarily determined either with the machine driven by a small direct-current shunt motor, or with the machine operating as a shunt motor.

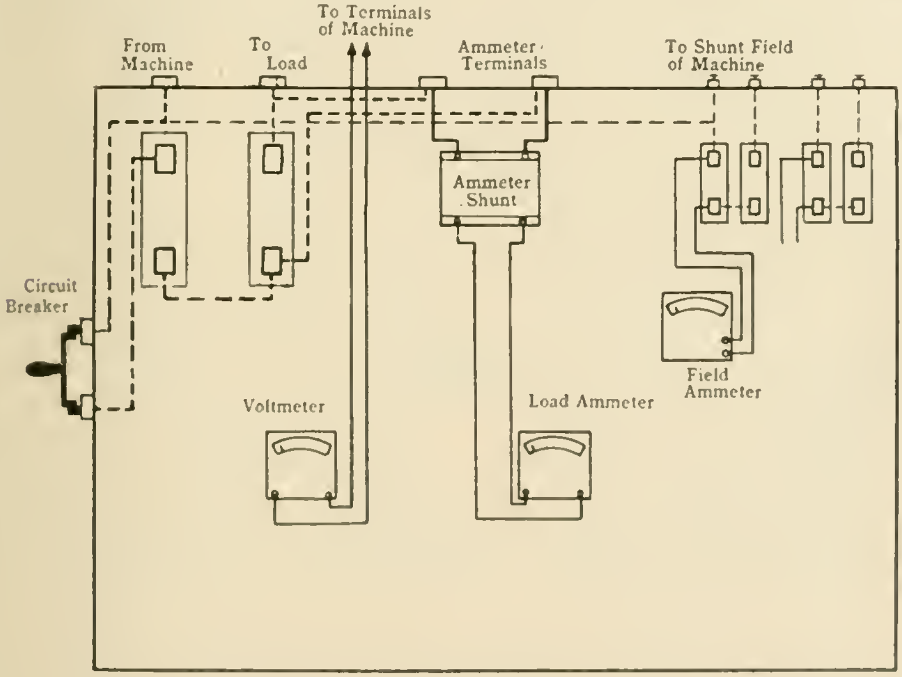


FIG. 5—DIAGRAM OF CONNECTIONS, TEST TABLE NO. 2

Core Loss with a Separate Driving Motor—In obtaining data for the core loss by this method, the machine is belted to a small shunt motor, preferably of the commutating-pole type, and driven at its rated full-load speed with the armature circuit open and the field separately excited. The shunt motor used to drive the machine under test should be of such a size that the friction losses of the machine under test are not less than one-quarter load on the driving motor and that the total losses at the maximum voltage do not exceed one and one-quarter load on the driving motor. The pulleys on the machines must be selected so as not to run the driving motor more than 15 percent above its rated speed. The belt selected should be as light weight as possible to carry the maximum loss without slipping, and excessive belt tension must be avoided, as pressure from this cause or from a heavy belt will cause increased friction which will necessarily have to be charged to the machine, although it is not a part of its normal losses. A spliced belt should be used if one can be secured, as a laced belt, especially with metal or patent lacing, causes the voltmeter needle to fluctuate.

The machine should be connected as shown in Fig. 6. The voltage of the power supply circuits should be free from sudden changes and easily regulated by the field of the power generator or by a booster in series with the line. Before the test is started, all wiring should be carefully checked and the bearings should be inspected and filled to the proper level with oil. After the machines are brought up to speed the field of the machine under test should be energized and an inspection made for mechanical defects, excessive vibration, etc. The machine should be run until the brush and bearing friction bcomes constant, as shown by the ammeter of the driving motor, and until the commutator is polished and free from dirt and oil. Several readings of the current taken by the driving motor should be noted when the armature is at constant speed and with no field on the generator. The average of these is to be taken as the basis for calculating the core loss.

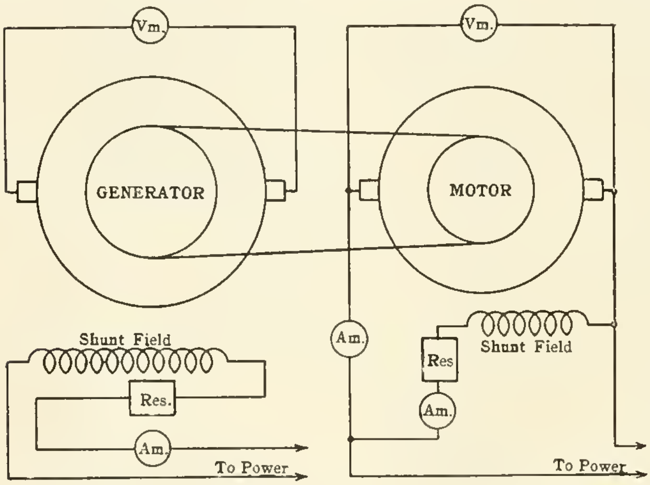


FIG. 6—WIRING DIAGRAM FOR FRICTION AND IRON LOSS TEST OF GENERATOR USING SEPARATE DRIVING MOTOR

The fields of the machine under test should then be excited to give about one-fifth normal voltage and simultaneous readings should be taken of the armature current, armature voltage and field current of the driving motor, and of the armature voltage, field current and speed of the machine under test. The voltage of the tested machine should then be increased by suitable increments, taking complete readings at each point, and occasionally checking the friction reading. The test should be continued up to 35 percent over normal voltage, making about 10 or 12 complete readings.

Friction and Windage—Raise all brushes off the commutator of the machine under test and take a complete set of readings on the driving motor; then excite the field of the machine with current to give normal voltage, and take another complete set of readings. Then with the belt off, take a no-load reading on the driving motor with the same field current as was used for the no-field reading in the core loss test.

Core Loss with Machine Operating as a Shunt Motor—Connect the machine as shown in Fig. 7, to a circuit in which the voltage can be varied from 30 percent of the maximum voltage to 25 percent above normal, with the commutating-poles, if any, in series with the armature. The same precautions must be observed as in the previous test to have the commutator clean and free from oil, the brushes on the no-load neutral position, and to run the machine until the friction becomes constant. Then reduce the armature voltage as low as possible, holding the speed constant by adjusting the shunt field so as to get a reasonably steady reading of the armature current. Adjust the shunt on the commutating winding if necessary to give stability. Note carefully the field current necessary to hold normal speed under these conditions, then lower it until the machine is running about 10 percent overspeed. The main circuit is now opened for a few seconds, thus allowing the residual magnetism in the field to die out. This is done that the test may be made under a condition of increasing excitation. The field should be excited again to the value previously noted and the armature circuit closed; this operation must be performed before the speed of the machine has dropped much below normal. The correct speed and the low armature voltage previously obtained should then exist and a complete reading may be taken. Increase the voltage by suitable increments, adjusting the field current at the same time so as to hold normal speed. Readings should be taken up to 25 percent over voltage in steps of about 10 percent.

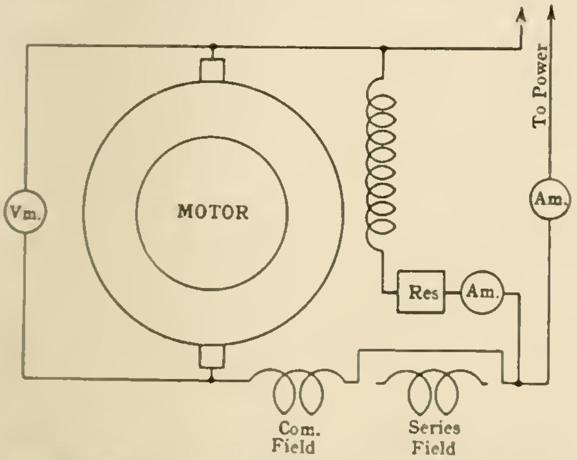


FIG. 7—WIRING DIAGRAM FOR FRICTION AND IRON LOSS TEST WITH GENERATOR OPERATING AS A SHUNT MOTOR

To determine the brush friction, in watts, take a reading at normal voltage with all the brushes raised except enough to carry the armature current, noting the total number of brushes and the number of brushes raised.

This method of determining core loss is inherently difficult unless the voltage is absolutely constant. It is usually made with a booster in series to control the voltage, but on account of the momentum of the revolving part any slight variations in line voltage will cause a large variation in current, so that care must be taken that the machine is neither accelerating nor decelerating when the readings are taken.

Saturation—The saturation at no-load with the brushes on the no-load neutral position is usually obtained at the same time as the core loss by reading the shunt field current at the time the other readings are taken. This test should be made with increasing field excitation unless otherwise specified. When taking the saturation, increase the field current very carefully so as not to exceed the desired voltage; if the desired voltage has been exceeded, take the reading at this voltage and proceed to the next point. When it is absolutely necessary to reduce the field to obtain a desired reading, the circuit must be opened for a sufficient length of time to allow the residual magnetism to die away. If this is not done, the effect of the residual magnetism from the higher excitation will be added to the flux at the lower value, and the voltage reading will be higher than that produced by the excitation due to field current alone. All saturation curves should be carried well over the knee and to at least 35 percent over the normal voltage.

EXPERIENCE ON THE ROAD

LEONARD WORK

Construction and Engineering Dept. Isthmian Canal Commission, Pedro Miguel, C. Z.

IN an interesting experience with an alternator some time ago, the difficulty was a failure to maintain full voltage except at very light load. The machine in question was the mainstay of a plant supplying the lights in a town of moderate size. It was of the old single-phase compensator type, and the correctness of its design and construction was attested by its long period of service, during which it had changed owners and location repeatedly, doing its work well under all sorts of conditions and abuse. The same trouble had been experienced with this machine previously, but at that time nothing more serious was found than an incorrect setting of the compensator brushes, the effect of which was to lessen the amount of rectified current in the auxiliary field. Proper setting of these brushes remedied the matter, and there was no further trouble in maintaining voltage for about a year.

The conditions which brought about a second investigation were, as reported by the manager, a falling in voltage with rise of load; generator fields hot; exciter fields very hot, and rheostat resistance all turned out. The engineer sent to investigate this case found, as on the previous visit, the compensator brushes improperly spaced. It required but a few minutes to reset these and to place the machine in service again, but, contrary to expectations, it was seen upon throwing on a load that but little improvement had been made. An ammeter connected in the auxiliary field circuit showed the proper current, and since a test of the coils proved none of them grounded or short-circuited, it was evident that the trouble lay elsewhere. The heating of the main field coils suggested the possibility of a diversion of current from some of them by ground or short-circuit, thus necessitating high excitation of the others, but an examination showed them to be free from either condition and that they all were heating alike. Armature coil trouble seemed not without the range of probability, for in some of the old alternators with concentrated windings of high reactance the armatures have been known to operate for a considerable time with one or more coils short-circuited. A test of these was made by connecting the collector rings with a source of alternating e.m.f. and observing the voltage across each coil with the armature at rest, but in each coil it was alike. The armature was not at fault.

Again returning to the fields, this time with a view to finding out of some of them were reversed in polarity, which would easily account for the failure in voltage, they were tested by temporarily short-circuiting each in turn, but, since during this operation the voltage fell slightly, it was seen that each coil was doing its work, and upon checking the magnetic polarity of each field coil with a compass they were found to be alternately north and south. There seemed little else to be tried but the speed, and this was found to be normal.

It appeared to be an extraordinary case. The armature was intact, the speed normal, the field excitation so high that the coils were heated to the limit, and the load less than the rated capacity of the machine; yet it was impossible to keep up full voltage. The one salient fact in such cases as this is that there is always a cause, however obscure it may be. The finding of the cause in an intricate or difficult case is largely a matter of perseverance and ability on the part of the investigator to leave no points overlooked. Upon inquiring into the character of the load carried by this plant it was learned that formerly the demand for current was principally for lighting, but that recently a number of motors, small units of the single-phase type, had been connected to the lines.

The question of power-factor, which had not before been considered, became at once of importance and while there were, unfortunately, no instruments at hand to determine this quantity, it seemed to offer a satisfactory explanation of the cause of the trouble. The demagnetizing effect of a lagging current would, of course, cause a reduction of field flux at the poles and consequently a reduction of armature voltage. Accepting this theory, it was next in order to remove the trouble. At first sight this appeared to be fully as great a problem as the locating of it had been. To attempt to raise the power-factor was, of course, out of the question. To increase the generator speed would increase the voltage, but would also change the frequency, and this obviously would be wrong. An increase in field strength where the coils were already heated to nearly 100 degrees C. did not appear possible. The question was really not only that of raising the generator voltage, but of reducing its field operating temperature, and at the same time increasing the total field flux; to lower the exciter operating voltage and incidentally the exciter field temperature. The whole was successfully accomplished by a simple change of field circuits on the alternator.

It was noticed that the exciter whose normal voltage was 125 volts was operating at 150 volts, but that its current output was only one-half its rated capacity. It had also been observed that the wire on the auxiliary field of the generator was about twice the size of that on the main fields, and much heavier than required for the rectified current circulating in it. From a survey of these conditions it seemed possible to obtain an increase in total field flux in the generator by dispensing with the compensating current and sending the main field current also through the auxiliary winding. Accordingly the main field circuit was re-connected into two circuits in parallel and these were connected in series with the auxiliary field circuit.

When the machine was placed in service again the result was seen to be all that could have been expected. It was possible to raise the generator voltage far above that required for full load; the main field windings, being in parallel, with a much reduced current in each, ran cool; the exciter, operating on a circuit of lower resistance, required less than normal voltage, and its own fields returned to normal temperature. Incidentally the exciter output was still below its capacity and the auxiliary field winding ran quite cool.

STARTING MILL MOTORS

W. B. LEWIS

Inquiry No. 787 in the Question Box leads me to cite a case of mill operation in which the motors are started synchronously with the turbine generator. When the plant is shut down at night the turbine throttle is closed and the turbine stops together with all the motors. In the morning an engine-driven exciter is started and full excitation is applied to the turbine generator field. The throttle of the turbine is then opened and all the motors start up with the generator.

This method of operation has been used for six years, and practically no switches are operated on the switchboard, not even the generator field switch. The line current never exceeds normal running current, and all mechanical and electrical strain on the system seem to have been reduced to a minimum. The method is particularly favorable in the case cited, as there are a number of 100 horse-power squirrel cage motors, the starting of which in the usual manner by means of an auto-starter would be more or less troublesome.

THE JOURNAL QUESTION BOX

OUR subscribers are invited to use this department as a means of securing authentic information on electrical and mechanical subjects. The topics should be of general interest and care should be used to include all data necessary for an intelligent answer.

A stamped, self-addressed return envelope should accompany each inquiry. Address all questions to Question Box Department, care THE ELECTRIC JOURNAL, 200 Ninth Street, Pittsburgh, Pa.

840—Field Pole Polarity—In dedetermining whether a field pole of a generator is of north or south polarity, is the end next to the armature winding the end of observation? O. M. (IDAHO)

The north pole of a generator is one in which the flux, according to the usual conventions, passes from the pole to the armature. According to the law that similar poles repel and dissimilar poles attract one another, this pole would be the one in which the end nearest the armature repels the north seeking or positive pole of the compass. This is evident also from the convention that the positive direction of flux, which is from the north to the south pole through the air, is that in which the north seeking end of a compass moves. Confusion arises frequently from the fact that the geographic north pole of the earth is a magnetic south pole. The north end of a compass points to the same pole of a generator or any other magnet that it does of the earth; namely, the magnetic south pole. In testing a generator, especially if it is fully excited, considerable care must be exercised that stray fields do not give misleading results, and that the powerful generator field does not reverse the polarity of the compass needle.

C. R. R.

841—Testing Interpole Fields—I have four interpole fields which were taken out of a 40 hp, 500 volt railway motor. It is believed that these coils are slightly damaged internally, but the damage seems to show only when the coils are hot. I would like to test them on full-load current; can you suggest a method for putting in the necessary resistance to cut down the current on a 500 volt circuit? Some method that will require only such material as can usually be found around a street railway repair shop. R. S. V. (N. Y.)

Make three water rheostats out of three large sized barrels. Connect these in parallel. Connect the 500 volt circuit through a circuit breaker to the field to be tested and the other side of the field to one lead from the rheostats; ground the other rheostat lead. Put hot water into the barrels and add a very little salt to each. The reason for not using cold water is that too much salt has to be put in at first to obtain the required current, and when the water heats up its resistance decreases so much that the rheostat becomes useless. By adjusting each barrel separately this group will handle the full load current of a 40 hp motor continuously. One barrel alone may be used if an overflow pipe be arranged about eight inches below the top of the barrel and a continuous flow of cold water be supplied by a hose. To make a water rheostat put a large piece of flat scrap sheet iron in the bottom of the barrel; twist the end of an insulated cable to it and connect this cable with the field. Attach a rope to a similar piece of sheet iron so that it will hang parallel to the bottom of the barrel. Hang it in the barrel and pass the rope over an old trolley wheel (which may be fastened to a board nailed to a post or placed across the top of the barrel) and tie some scrap metal on the other end to act as a balancing weight. Attach a cable to this plate and ground the other end, after connecting the circuit through an ammeter shunt. L. T.

842—**Effectiveness of Choke Coils without Lightning Arresters**—Will you kindly inform me if it will be of any use to connect a set of choke coils without lightning arresters in series in each line of a 6000 volt, three-phase, 50 cycle circuit? I have been told that the choke coils will protect the series transformers by choking back the lightning. Lightning arresters are connected on the same line at a point 2000 meters from the place where the installation is made.

J. A. (MEXICO.)

Choke coils having considerable inductance would afford appreciable protection to the series transformers. If the choke coils are small and of few turns they will not afford much protection. The usual method of protecting series transformers is to shunt them with a 1/32 inch gap of non-arcing metal.

R. P. J.

843—**Wattmeter with Series Transformer**—We have a 400 to 5 ampere transformer and a 100 ampere meter for a circuit carrying about 300 amperes. We also have a 100 to 5 ampere transformer. What would be the result if we should connect the 5 ampere coil of this transformer in series with the secondary of the 400 to 5 transformer and then connect the meter to the 100 ampere coil?

W.P.M. (UTAH.)

The double transformation of current would not give accurate results. There would be an error in both the strength of current and the phase angle between shunt and series currents in the wattmeter. Current transformer ratios are not the same when stepping up current as when stepping it down. The wattmeter would operate when connected as proposed but would read low unless specially calibrated in connection with the transformer outfit. It would not be possible to calibrate the outfit so that it would be accurate on varying load conditions. The only reliable combination possible would be to use a meter wound for low current so that it would operate from the secondary of a suitable current transformer direct. Possibly the 100 ampere meter could have its series coil rewound with 20 times the present number of turns, thus adapting it for use with a transformer giving five amperes secondary.

H. B. T.

844—**Method of Drying Oil**—I am about to install some 44000 volt electrolytic aluminum cell type lightning arresters, and the oil, having stood for some time out of doors in the original iron tanks before I took charge, has moisture in it. Please recommend some easy satisfactory method for drying this oil. The company that I am with has no oil filtering and drying outfit.

A. W. S. (TENN.)

There is probably no more satisfactory method of drying out oil than by the use of an oil filtering and drying outfit such as supplied by electrical manufacturers. Various other scheme are used, but all have objections of one kind or another. Where no drying filter is available, it is possible to dry the oil by placing it in a large tank and allowing it to stand for several days until all the water is separated, drawing this off from the bottom and then completing the drying by applying heat either by resistances immersed in the oil, or by some other means of holding the oil at a temperature of 90 to 100 degress C., until the dielectric tests show that the drying is completed. This process will require days and possibly even weeks, and, besides discoloring the oil somewhat by the high temperature, it will be more or less dangerous from the fire hazard standpoint. Another method is to drain off the water as before and place a quantity of unslaked lime in the tank and by agitation get this thoroughly in contact with the oil, absorbing any moisture which may remain. In this case the oil will have to be filtered or allowed to settle until the clear oil can be drawn off, so as to eliminate the lime. This will cause some loss of oil, but will be much cheaper and more rapid than the drying by heat. If means are at hand for passing the oil through heavy filter paper which has been well dried and the paper changed as it takes up moisture, the drying can be satisfactorily accomplished. The dielectric test always shows whether or not the oil is in proper condition. Oil properly dried should stand a test of 30 000 volts between ½″ spheres set 0.15″ apart. To test for moisture, shake a sample of the oil thoroughly in a test tube with a little anhydrous copper sulphate. A blueish tinge in the copper sulphate indicates moisture. Or plunge an iron rod, heated to a temperature just below red heat, into a sample. A hissing or crackling noise indicates the presence of moisture.

C. E. S.

845—Method of Securing Patent—Please let me know which is the best way to patent a machine or part of a machine. Is it better to apply direct to the main office in Washington, D. C., so as to avoid frauds? If so please give me the right address.

M.T.C. (HONOLULU.)

The following quotation is taken from Article 17 of the Rules of Practice in the United States Patent Office.

> "An applicant or an assignee of the entire interest may prosecute his own case, but he is advised, unless familiar with such matters, to employ a competent attorney, as the value of patents depends largely upon the skillful preparation of the specification and .claims."

By reason of the fact that the protection offered by a United States patent depends very largely on the competence with which the application was prepared and prosecuted before the Patent Office, many valuable inventions have been practically lost to the inventors. It is therefore always advisable to secure the services of a competent patent attorney. R. J. D.

846—Electric vs. Pneumatic Oil Switches—Please give me the relative advantages and disadvantages of electrically versus pneumatically operated oil switches as regards cost and reliability of service.

P.R.M. (CAL.)

Assuming pneumatic operation to mean "electro-pneumatic," they are equally reliable and quick acting. Plain pneumatic operation would be very sluggish in action through pipe lengths of any considerable distance. Electro-pneumatic operation requires a source of air supply in addition to electric supply, while only the latter is necessary for plain direct-current electrically operated apparatus. The source of compressed air is usually a motor-compressor and air storage system which would add considerable cost and complexity to a small switch installation. Where alternating current only is available and large switches or circuit breakers are to be handled, electro-pneumatic operation with alternating current valve magnets is a very effective combination at a reasonable cost. In general the cost of switching apparatus operated with either direct-current electric or direct-current or alternating-current electro-pneumatic control is nearly the same. The difference in installation cost is in the source of electric and air supply J.N.M.

847—Rewinding Small Transformers—I wish to rewind a small transformer, the core of which is a laminated ring having a cross-section of three-quarters of an inch by one inch and an internal diameter of two and three-quarter inches and outside diameter of three and one-half inches, to operate continuously on 115 volts and deliver ten volts at the secondary terminals. Will you kindly furnish data as to size of wire and amounts for both primary and secondary winnings. P.J. (OHIO.)

One of the dimensions given in the above question is wrong, since a ring having a cross section of ¾ x 1 inch and an internal diameter of 2¾ inches must have an outside diameter of 4¼ or 4¾ inches depending upon which of the cross-sectional dimensions is in the radial direction. We will assume that the ring has a cross-section of ¾ x 1 inch and an internal diameter of 2¾ inches. It does not matter whether the outside diameter is 4¼ or 4¾ inches. Assuming a frequency of 60 cycles there will be required about 120 turns for the 10 volt winding and 1 380 turns for the 115 volt winding, the ratio of turns being the same as the ratio of voltages. The wire would preferably be double cotton covered, that for the 10 volt winding being approximately 12 times the cross-sectional area of the wire for the 115 volt winding. The sizes of wire can be made as large as can be wound in the available space. Probably No. 9 B & S gauge can be used for the 10 volt winding and No. 20 for the 115 volt winding. There should be two or three layers of tape between the two windings. W.M.M.

848—Iron for Laminated Cores—Will you please advise me what kind of iron is commonly used in the laminated field and the armature of alternating current machines. Do you know of any company from whom I could purchase the stampings for small motors, from 1 to 15 hp. I am trying to determine if it will pay us to build alternating-current motors to go with a line of centrifugal pumps, of which we build a large number.

W.D.L. (WASH.)

Laminated field cores for motors are usually made up from a special grade of open hearth steel, the thickness varying somewhat as used by different manufacturers; the minimum thickness used commercially is approximately 0.0125 inches and maximum not over 0.025 inches, the average being No. 27 sheet steel gauge (or 0.0172 inches). Various sheet steel manufacturers put material on the market under the name of electrical sheet, and such sheets can be purchased from a number of manufacturers. We do not think that it is probable that you could produce alternating-current motors as cheaply or of as good quality as they can be purchased from the large manufacturers. G. S.

849—Power for Starting Alternator—What k.v.a. at 600 volts we would require to start a 300 kilowatt, two phase, 60 cycle, 2 200 volt, 514 r.p.m., revolving field type alternator with "straight pole" construction, i.e., with laminated poles, without overhanging pole tips, direct connected to a 300 kilowatt direct-current machine? The machine was designed for belt operation. Would it be likely to lock and could it be started satisfactorily? A starting compensator would be used to reduce the potential to 600 volts.

J.B.A. (GEORGIA.)

Although this machine was probably designed for generator operation with no starting winding, there is a bare possibility that, with a suitable voltage applied, the eddy currents induced in the pole faces and brass wedges between the poles (if any) would be sufficient to start the machine. However if this test is made the voltage applied should be about 1 000 volts, as 600 volts is too small a voltage to be applied to a machine of this type. If direct current is available, it is much preferable to start the outfit from the direct-current unit. In all probability, an induction starting motor with 12 poles will have to be direct coupled to the outfit if it is not possible to secure direct current for starting. For further information see Nos. 12, Jan. 1908; 175, Nov. 1908; 376, Mar. 1910; 570, July 1911; 76, June 1908; 305 and 306, Sept. 1909; 470, Aug. and 4470, Sept. 1910. R.K.

850—Permeability of Iron and Air—How does the permeability of iron vary with the flux density? How does it vary with the magnetizing force *H*? In a certain text book the equation was found M=B÷H. Is this correct? Why is *H* equal to *B* in air?

G.H. (ONTARIO.)

The permeability of a sample of iron varies with *B* and *H* as follows:—To obtain the curve showing relation between permeability and flux density start with the magnetization or *B-H* curve of the sample and plot the ratio $\frac{B}{H}$ against *H*.

The equation $M = \frac{B}{H}$ is the correct expression for permeability provided *B* and *H* are expressed in proper units. *B* must express the flux density in magnetic lines per square centimeter. *H* must be expressed in *Gausses and not ampere-turns per inch*. *H* in gausses equals $0.4\pi ni$ where n=the number of turns per centimeter of length and i = the current in amperes. Since air has constant permeability at all inductions it has been taken as the standard or medium of unit permeance. The units *B* and *H* have therefore been so chosen that $B = H$ in air, or $\frac{B}{H} = 1$.

L.C.W.

851—Cross Currents with Grounded Neutrals—We have been using a transformer wound as in Fig. 851 (a) to obtain a neutral on a three-phase, four wire (grounded neutral) system. The transformer is 17½ kw, 60 amperes per phase, 400 volts. It was used mainly when rotary converters were running inverted, the alternating-current generators being shut down. We have discovered that this transformer can remain in service when a 2 000 kw alternator is in operation, but twice it was accidentally left in with a 750 kw alternator when it took a heavy cross-current to its neutral, being red hot. No discrepancy is noticeable on phase to ground voltage of either machine or the transformer when operating alone. There being no air-gap in the transformer magnetic circuit, how can it take a heavy cross-current which can be but a magnetizing current to balance a displaced neutral in "Y" connection. F.J.S. (ILLINOIS).

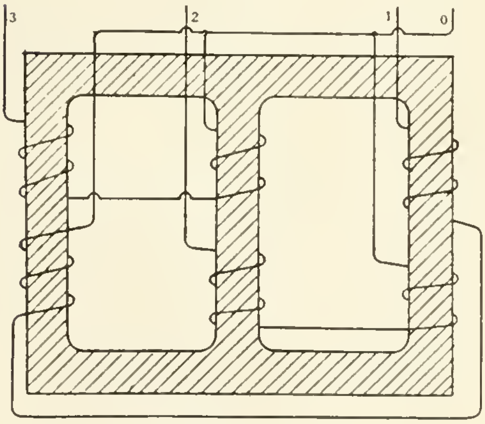


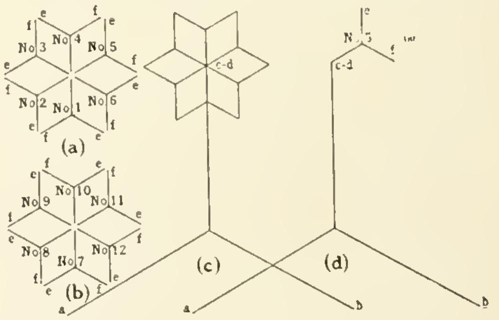
FIG. 851 (a)

The trouble here is probably due to the wave form of the 750 kw generator, which must have a third harmonic component in the e.m.f. wave from line to neutral. To such a component the transformers simply act like an air choke coil, and a current will flow through the transformer winding to the neutral point and through the generator. It is not necessary to ground the generator if the transformer neutral is grounded. C.F.

852—Determination of Polarity of Y—Y Connected Transformers for Parallel Operation—In an article by Mr. W. M. McConahey in the JOURNAL for July, 1912 the method of determining the polarity of transformers connected in Y on both the high and low-tension sides was purposely omitted, as noted on page 618, because of its being rarely used. As we have a case of paralleling of such units, however, we would appreciate information covering these conditions.

W.H.E. (OREGON.)

The following table indicates the measurements covering the various combinations shown in Figs. 852 (a), (b), (c) and (d). The table is the same as that for



Combination	Voltage Relations			
1	af = be	af < ae	bf > be	af = ac — df
2	af = be	af > ae	bf > be	ae = ac — de
3	af = be	af > ae	bf > be	bf = bc + df
4	af = be	af > ae	bf < be	be = bc + de
5	af = be	af < ae	bf < be	ae = ac + de
6	af = be	af < ae	bf < be	bf = bc — df
7	af = be	af > ae	bf < be	ae = ac — de
8	af < be	af < ae	bf < bc	af = ac — df
9	af < bc	af < ae	bf < be	be = bc + de
10	af = bc	af < ae	bf > be	bf = bc + df
11	af > be	af > ae	bf > be	af = ac + df
12	af > be	af > ae	bf > bc	be = bc — de

FIG. 852 (a), (b), (c) AND (d)

the delta-delta connection given in the article. Using this information in connection with that given in the article, the polarity of a Y-Y connected transformer can readily be worked out. W. M. M.

853—Increasing the Speed of Induction Motor—I desire to increase the speed of an induction motor from 560 r.p.m. to 1 130 r.p.m. I reconnected the motor for 6 poles but after running a few minutes it would blow the 20 ampere fuse on no load. The motor is 7.5 horsepower, three-phase, 60 cycle, 400 volts, 11 ampere per terminal. Please explain the difficulty.

G.T.L. (NEVADA.)

The effect of the change in the number of poles from 12 to 6, other conditions remaining the same, will be to decrease the magnetizing current, neglecting saturation, in the ratio of 6^2 to 12^2 or 1 to 4. But since with the six pole connection the pole pitch has been doubled and the throw of the coils has not been correspondingly increased, the number of electrical degrees spanned by the coil will be decreased from 162 degrees to 81 degrees with the result that the magnetizing current will be increased, neglecting saturation,

$$\text{in the ratio } \left(\frac{\sin \frac{162}{2}}{\sin \frac{81}{2}} \right)^2 \text{ or } \frac{2.26}{1}$$

Combining these two effects, the magnetizing current will be decreased, neglecting saturation, in the ratio $\frac{1}{4} \times \frac{2.26}{1} = \frac{2.26}{4} = \frac{1}{1.75}$ and, as the iron of this motor is not appreciably saturated, this ratio will be practically true considering saturation. Since the no-load current of an induction motor is made up mostly of the magnetizing component, and is not affected to any great extent by variations in the power component, the no-load current in this case, if the motor was properly reconnected from 12 to 6 poles should be considerably decreased instead of increased. This excessive no-load current must be attributed to some other cause, and the improper reconnection of the winding for 6 poles seems the most probable one. The fact that there are 120 coils, and 18 groups in the 6-pole, three-phase winding, which requires that there be $\frac{120}{18}$ or 6-2/3 coils in series per group, makes it necessary to unequally distribute the coils in the different groups, and if this distribution is not properly made an unbalancing of the winding may result, causing excessive no-load current. The proper distribution of the coils should be as follows:—

No. of coils in series per group,	6	7	7	7	6	7	7	7	6
Poles......		N			S			N	

Repeat this for the remaining 3 poles. All groups per phase should be connected in series for 400 volts and the three phases connected in star in the standard manner. The winding should be checked, and the connection of the groups checked for the proper polarity. By checking for polarity is meant the proper succession of north and south poles in a given phase and in addition checking the proper 120 degree relation between phases. A method for making this latter check was given by Mr. H. C. Specht in the **Journal** for June 1911, Page 571, and is briefly as follows:—Assuming the current going in all three leads toward the center of the star or Y, place an arrow opposite each polar group showing the direction of the current through that particular group. Taking the polar groups in order around the machine for all three phases these arrows should alternate in direction thus—A phase >, B phase <, C phase >, A phase <, B phase >, C phase <, etc. around the machine.

854—Method of Starting Motor Generator Sets—In railway motor-generators using self starting synchronous motors, which is best method of starting: to start from the alternating-current side or start from the direct-current side, synchronizing the motor with the alternating-current supply? C.L.G. (TEXAS.)

This depends to some extent on the individual case. In a great many substations where a single set is used, direct-current is not always available for starting. Where it is available this method has the advantage of causing relatively less disturbance to the line than alternating current, but on the other hand it is much less simple as it requires starting equipment for the direct-current side, and synchronizing equipment for the alternating-current side. Alternating-current starting momentarily takes a relatively large current from the line, which for railway work is usually of no consequence. It has the marked advantage of simplicity both of operations and equipment required, auto-transformers and a switch for the alternating-current side only being necessary; hence the latter method is generally preferred.

R.A.M.

855—Telephone Despatching—Our company operates its trains on most of its lines by telephone. An operator in station A can ring up B without the other offices on the same line being signalled. How is this done?

G.H. (ONTARIO.)

In general the control of trains by means of telephone train despatching systems includes a dispatcher's office and a number of block stations along the line. Communication can be established by means of the system between the dispatcher and any stations along the line without the other stations being signaled; or, communication can be established between two stations on the line without other stations being affected. This result is obtained by means of a number of sending keys and selective relays connected in parallel with the telephone line, one key and one selective relay being located at each station, this of course including the dispatcher's office. The sending device in some cases consists of a push button board where the buttons are numbered to correspond with the stations along the line. When one of the buttons is pressed it sends all along the line, not a continuous current, but a series of impulses, whose frequency and duration depends on the special combination assigned to that button, much in the same way as the grooves in the key of a Yale lock. Some selective relays are built on the escapement principle (similar to that used in a clock) and, as before stated, they are all connected in multiple on the line. All of them are consequently affected by each signal sent out along the line, no matter from what station. When, for example, a certain signal is sent out from a station from push button No. 10, this signal consisting of say ten impulses, makes all the selective relays work through ten movements. In selective relay No. 10, located of course in the station corresponding to that number, a contact is made after the relay has moved through ten impulses so that the operator in that station receives a signal. The contact is made by each of the other selective relays along the line depending upon the number of impulses sent out; for example, when six impulses are sent out, all the selective relays stop at a point 6, but the circuit is completed only on point 6 in the case of selective relay No. 6. It will, therefore, be seen from the above brief description that each selective relay responds only to its own peculiar combination of impulses. This description is not intended to cover any particular design of apparatus, but is given only with the idea of illustrating the principles on which the selective system works. L.F.H.

856—Magnetic Side Pull in Motors—*a*—In a parallel wound direct-current armature with equal resistance in all branches of the circuit, is there any magnetic side pull if the armature is displaced so as to give unequal air-gaps? *b*—Does the addition of cross connectors between equipotential points in the armature tend to lessen such side pull? *c*—Is there any side pull theoretically in a squirrel cage induction motor? H.A.F. (NEW JERSEY.)

a—With unequal air-gaps there will be an unbalanced pull toward the pole nearest the armature, as the flux from this pole will be greater than from the others. The conductors coming under the influence of this pole, however, will have induced in them a higher e.m.f. than the remaining conductors and consequently the circuit including these conductors will furnish more than its proportion of this total current. This increased current will result in increased armature reaction, which in turn tends to equalize the strength of the poles and the distribution of current among the several circuits. *b*—With the addition of equalizer connections alternating currents are set up through these connections and produce a much stronger armature reaction than the direct currents in (*a*), resulting in a still further demagnetization of the pole nearest the armature and consequently a much better equalization of current than is obtainable without their use. It should be noted that the alternating currents which flow through the equalizer connections act almost directly against the magnetization of the pole producing them, while in (*a*) the currents flowing through the commutator and brush holder connections are principally distorting in their effect upon the field and only partially demagnetizating, and hence cannot produce as great an equalizing effect as the alternating currents. *c*—Theoretically, there is no unbalanced pull in a squirrel cage motor having a fairly low resistance in the bars and short-circuiting rings. It may happen, however, with a fairly high resistance in the secondary winding, that the action of the local balancing currents is interfered with and there may be some unbalanced magnetic pull. With a slip not exceeding four or five percent this is very unlikely to happen.

H.C.W. AND A.M.D.

857—Restoring Gun Metal Finish—How can the gun metal finish on switch board instruments be restored and where can the necessary articles be obtained?

N. J. R. (PENNA.)

In order to refinish instrument cases with the gun metal finish it is necessary to have quite an elaborate equipment which would make it impracticable to attempt to apply the process on a small scale. If it is essential to have the instruments so finished it would be advisable to take the matter up with the manufacturers with the idea of having them do the work. A very satisfactory substitute would be found in the use of a black lacquer finish. Suitable lacquer can doubtless be obtained by referring to the manufacturers of such instruments.

E. R. S.

858—Use of Enameled Wire—Please inform me as to the practibility of using enameled wire for field windings on air compressors. In winding, is there any tendency for the insulation to crack when the first layers are being wound on the form?

A.L.S. (OHIO.)

Enameled wire has been used successfully for field windings on compressor motors. If the wire is of good quality, it should stand bending around a radius approximately 2½ times its own diameter, without cracking the enamel. R.F.F.

859—Wire for High Voltage Secondaries—For winding the secondaries of induction coils or high voltage transformers, say from 100 000 volts to 200 000 volts, which is best to use, enameled or silk covered wire?

N.J.R. (PENNA.)

For winding secondaries of induction coils or high voltage transformers, it would probably be better to use a single cotton covered enameled wire. This would be preferable to the plain enameled wire both as regards mechanical strength of the insulation and its electrical strength. Silk covered wire or silk enameled wire would be much more expensive. For induction coils, simply cotton covered wire is often employed, the secondary winding being segregated into a number of what are called "pies," properly insulated from one another and connected in series to make up the total secondary winding. E. R. S.

860—Starting Frequency Changer—(a)—A frequency changer of 1 000 k.v.a. capacity is at the end of a 50 mile, 34 600 volt, transmission line. The generator at the generating station and the frequency changer are wound for 2 300 volts and 250 amperes. One generator is furnishing power to a town four miles away, which consumes about 600 kilowatts. Will a second generator in parallel with the one already furnishing power be sufficient to start the frequency changer, and yet not interfere with sending power to the town four miles away? If so, what would be the best method to pursue, both as to getting the machine started and for raising the voltage at the instant the frequency changer is cut in. Each generator has a capacity of 1 000 k.v.a. at 25 cycles. No Tirrill regulator is used. Is there any method by which you can prevent the governors from seesawing when two 1 000 k.v.a. generators are connected in parallel, one generator carrying a load of 200 kw, the other being parallel with it. R.E.L. (OHIO.)

(a)—It is impossible to say definitely that a 1 000 k.v.a. frequency changer can be started from 2 000 k.v.a. in generator capacity, an existing load of 600 k.v.a. being on the generator, without knowing the characteristics of both generators and frequency changer. It is improbable, however, that the frequency changer can be so started without causing a decided voltage disturbance which would probably make the operation of other apparatus on the line unsatisfactory. The best method can only be determined from a complete knowledge of the starting equipment available and the relative locations of all the apparatus. In general, however, there is no method either by hand regulation or by Tirrill regulator for preventing a serious drop in voltage when a frequency changer is started from approximately the same generator capacity. (b)—We suggest that dash pots be applied on the engine governors. However, each case of hunting is a problem in itself and can only be solved by experiment. F.D.N.

861—Connecting Two Motors to Single Load by Belts—One 10 hp, three-phase squirrel cage motor is driving a shaft by belt. The load has been increased to 18 hp, and it is proposed to use another similar 10 hp. motor (which is in stock) rather than buy a 20 hp motor and stock this motor, which would increase the stock. The load unfortunately can not be divided. Can this motor be belt connected as the present one, and will the load be divided equally; if not how would you apply the second motor? F. V. (ENGLAND)

Two squirrel cage motors may be belted to the same load provided the pulley sizes are so adjusted that they divide the load equally. One method of accomplishing this is to choose the pulley diameters as nearly right as possible and then take wattmeter readings to see if the motors are sharing the load in proportion to their ratings. If this is not the case the pulley on the motor which is too heavily loaded should be slightly decreased in diameter until the two motors divide the load properly. The theory covering the electrical reasons back of this change is the same as that given for wound secondary motors in No. 750, June, 1912. A.M D.

862—Three Wire Generator and Balancer Sets—Why are three wire generator and balancer set combinations so popular for private plant installation? Is it solely because of the superior efficiency of the low-voltage lamps? What are the comparative efficiencies of 120 and 240 volt lamps? F.M.W. (MD.)

The incandescent carbon or metal filament lamp is inherently a low voltage device; where made for higher voltages in sizes suitable for house lighting the filaments are rather fragile for commercial use. For copper economy in feed wires and distributing mains a high line voltage is desirable. By using a three-wire circuit with voltage across the outer wires double that of the lamp voltage and using a neutral wire of one-half the section of the outers, a given amount of power can be distributed with the same percentage voltage drop as in the two-wire circuit with 5/16 the weight of copper. For complete information on direct-current balancer sets, see article on this subject in the JOURNAL for November, 1912, page 1036. A.C.L.

863—Current in Auto-Transformer Starter—If possible I would like you to explain by sketch the direction and quantities of currents in each phase of a three-phase auto-transformer starter, with a tapping of say 0.65, at the moment one phase is at a maximum, current assumed 60 amperes. What would happen if the star point of transformer was broken? F.V. (ENGLAND.)

Assuming 60 amperes (r.m.s.) through the auto-transformer, and that current in phase *A*, Fig. 863 (a), is at its maximum value, the current in phase *A* will be $60 \times \sqrt{2} = 85$ amperes and the values and directions of currents in the three phases of the auto-transformer will be as indicated. If the winding of phase *A* should become detached from the junction of the three windings at *O*, the windings *C O B* would act as a single-phase auto-transformer across phases *C B* and single-phase current only could pass to the motor through leads *c b* as shown in Fig. 863 (b). For further information refer to Nos. 303 and 668. W.R.W.

FIG. 863 (a) AND (b)

864—Calculating Current in Three-Phase Line—How do you calculate the load and current in the three wires or lines *A*, *B*, *C*, of a three-phase 200 volt supply with various numbers of 16 cp. carbon lamps taking 3.5 watts per candle-power connected to the different phases? F.V. (ENGLAND.)

The principles involved are indicated in the article by Mr. Chas. H. Porter on "Notation for Polyphase Circuits," in the JOURNAL for September, 1907, p. 497. See also an article by Mr. H. W. Brown on "Vector Diagrams Applied to Polyphase Meter Connections," in the JOURNAL for June, 1908, p. 342. The current in each line wire is the vector sum of the currents required by the respective loads across the two adjacent phases. If the unbalance of voltage due to unequal current per phase is negligible, the voltages of the three phases may be represented by three equal vectors at angles of 120 degrees from one another. The case of an incandescent lamp load is simplified by the fact that this is a non-inductive load and thus the line voltage and line current are in phase. The currents due to load on any two of the three phases can be combined vectorially to get the current in the line to which the two given loads are connected in common.

865—Speed of Alternator—I understand that 10 poles of a 12 pole machine may be removed and that the frequency will remain the same at the same speed. The armature winding of the machine in question is all in series. Of course, the voltage will be down and the balance may be off. Am I correct? I.V.F. (MASS.)

The frequency will be the same at the same speed, regardless of how many poles are removed, except, of course, if all poles are removed there will be no field and therefore no frequency. See also 768, September, '12. [illegible]

866—Reconnecting Three-Phase Motor for Two-Phase—We have a ten hp., 60 cycle, eight pole, 220 volt induction motor which is at present wound for three-phase parallel winding, three coils per group, 72 coils in all, thereby placing 12 coils across the line. Will you kindly advise if this motor can be reconnected for two-phase. G. F. N. (PENNA.)

Given a three-phase motor at a specified voltage, there will be required approximately one and one-quarter times as many turns in the winding if the same motor is to be operated on two-phase at the same voltage with the same flux densities in the iron and approximately the same performance as regards torque, power-factor and efficiency. In the example quoted, if the motor were reconnected for two-phase, the normal voltage to give a performance equivalent to the three-phase would be 176 volts on the parallel connection or 352 on the series. Since 220 volts is available only, the motor might be very much over-saturated if run on the two-phase parallel connection. The one way to get a satisfactory performance would be to rewind the motor with coils having one and one-quarter times as many active turns in the individual coil as on three-phase. Owing to the fact that this is an eight pole machine with 72 slots, when it is connected for two-phase the polar groups of the winding in each phase will be made up of four coils and five coils alternately. In parallelling the two halves of each phase winding, care should be taken to see that there are two groups of four coils and two groups of five coils in each side of the parallel connection in each phase. Failure to observe this would result in local circulating currents due to unbalanced induced voltage in the two sides which are in parallel and hence in series so far as local currents are concerned. When this problem is reversed and a motor is to be changed from two-phase to three-phase, there are, for the same reason, too many turns for equivalent three-phase performance. This is sometimes adjusted by leaving 20 percent of the coils dead and suitably distributing the dead coils around the machine. However, this introduces irregularities in the shape of the magnetic rotating field which impair the performance to some extent and this practice should be regarded as a territory makeshift rather than a permanent operating condition.

A.M.D.

867—Series Transformer Connections—In a set of three-phase, 25 cycle, 6600 volt bus-bars, three current transformers having 100-5 ampere ratio are inserted. It is desired to obtain three-phase overload protection by an oil circuit breaker which is to be tripped by means of a trip coil through one series relay at a ratio of less than 100-5 amperes. We have made connections as indicated in Fig. 867 (a). What will the current in the secondary circuit relay be when current per phase in primary is 100 amperes? By what method of connections can I make this secondary current five times $\sqrt{3}$ when 100 amperes per phase is flowing in the primary?

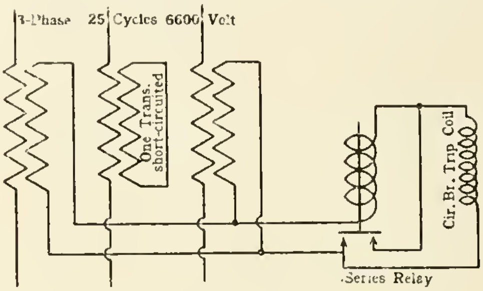


FIG. 867 (a)

J. S. K. (NEW YORK.)

It is not possible to completely protect a three-phase circuit from overload with one relay. With the connection shown, the secondary current should be approximately 8.6 amperes when 100 amperes balanced current is flowing in each line. For method and connection diagrams for the protection of polyphase circuits see articles by Mr. H. W. Brown on "Special" and "Standard Relay Connections" in the JOURNAL for July, 1909, page 433, and July and Aug., 1908, pages 406 and 460. C. F.

868—Parallel Operation of Two and Three-Wire Generators—Can a two-wire, compound wound generator be operated in parallel with one or more three-wire generators in which the series fields are split between the outside leads, half of the series field being in each of the outside leads? If so, what equalizing connections should be used, the three-wire machines being equalized between both sets of brushes? W. L. F. (PANAMA.)

Satisfactory parallel operation of direct-current generators involves: (1) That the machines have approximately the same saturation curve over the working range of the machine. (2) That the voltage drop across leads, series fields with shunts and additional series resistance if necessary, shall be the same when machines are operating independently at normal load. (3) That resistance of the equalizer shall be negligible. With the above conditions, the excitation of the series field will always vary in direct proportion to the kw capacity (series resistances being inversely proportional to kw). When the machines do not operate at the same points on the saturation curves, the regulation curves do not have the same shape and as a result, one machine will take a larger proportion of the total for light load and a less proportion under increased load. In operating two and three-wire machines together, the machines may work satisfactorily for balanced loads, but unbalancing disturbs this condition. If the unbalancing is in the lead for which there is no equalizer circuit on the two-wire machines, all unbalanced current returns through the series fields of the three-wire machines, over-exciting these and causing them to take the greater share of the load. If the unbalancing is in the lead for which there is a complete equalizer circuit on all machines, it is evident that the excitation of the three-wire machines will only be subjected to one-half the variation of the two-wire machines, as the former have but one-half the total series field in the variable circuit. In this case, therefore, two-wire machines will tend to take more than their share of the load. Any condition of unbalance, therefore, disturbs the system and tends to prevent satisfactory parallel operation. For further information, see article by Mr. C. I. Young, in the JOURNAL for Nov., 1911, p. 974.

R. H. T.

869—Changing Shunt Field Coil to Series Field Coil—(a)—What is the ratio of the resistance of a shunt field coil in a small motor, to that of a series field coil? For instance, is it possible to change the shunt field of a one hp 110 volt direct-current motor to a series field? (b) If a 65 volt three hp shunt motor runs at 700 r.p.m. at full-load, at what speed must it run as a generator to generate 70 volts, with all resistance cut out of the field and load of 20 amperes? (c)—In a three hp series motor, what will be the ratio in the drop in speed to the load applied? J. E. L. (PENNA.)

(a)—It is hardly possible to use the same coil, as the shunt coil is of high resistance, has many turns of small wire, and is intended to carry only a small current, while the series field is of low resistance, having fewer turns of larger wire, and carries the entire armature current. To change a shunt motor to a series motor the field coils would have to be entirely rewound, for approximately the same number of ampere turns at full load. (b)—This depends entirely upon the characteristics of the machine such as the resistance of the armature, etc., but will be roughly, from 850 to 1000 r.p.m. (c)—The ratio between the speed and load of a series motor depends on many features in the design and can best be expressed in the form of a curve. A characteristic speed-load curve for a small series industrial motor is shown in Fig. 869 (a).

C. O. S.

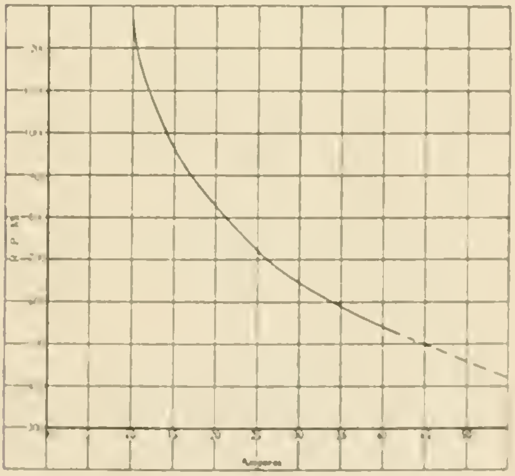


FIG. 869 (a)

870—Single-Phase Load from Three-Phase Transformer—What is the maximum single-phase load in amperes which may be connected to a single-phase circuit derived from a 100 k.v.a. three-phase transformer? (Assuming unity power factor.) W. L. F. (PANAMA.)

If the winding of a 100 k.v.a. three-phase transformer is connected in star as shown in Fig. 870 (a), it is designed to carry a current of $\frac{100 \times 1\,000}{V \times \sqrt{3}}$ = amperes, when *V* is the voltage between leads. If the transformer is connected in delta as shown in Fig. 870 (b), the winding is designed to carry a current of $\frac{100 \times 1\,000}{V \times 3}$ amperes. When single-phase current is taken from leads *1* and *2*, Fig. 870 (a), the current in the leads will be equal to the current in the winding *a* and *b*, therefore the single-phase current that corresponds to normal full-load $= \frac{100 \times 1\,000}{V \times \sqrt{3}}$ amperes. Single-phase current taken from leads *1* and *2*, Fig. 870 (b), will divide between two circuits, one circuit through winding *a* having an impedance of Z and the other circuit through windings *b* and *c* having a combined impedance of 2 Z. The current will divide between these two circuits proportional to 1/Z to 1/2Z or 1 to 0.5. When winding *a* is carrying a single-phase current corresponding to full load, windings *b* and *c* will be carrying a current of one-half that value, while leads *1* and *2* will be carrying the sum of the two currents or 1.5 times the current in winding *a*. Therefore, the single-phase current from leads *1* and *2* that corresponds to normal full load $= 1.5 \; \frac{100 \times 1\,000}{V \times 3}$ amperes. Assuming a secondary voltage of 6 600, the winding in phase *a* and *b*, Fig. 870 (a), will be carrying a full-load current when a single-phase current of $\frac{100 \times 1\,000}{6\,600 \times \sqrt{3}} = 8.75$ amperes is taken from leads *1* and *2*. With the same voltage but connected according to Fig. 870 (b), phase *a* will be carrying full-load current when a single-phase current of $1.5 \left(\frac{100 \times 1\,000}{6\,600 \times 3} \right) = 7.58$ amperes is taken from leads *1* and *2*. The same reasoning applies to either primary or secondary, and both windings must be considered.

J. F. P.

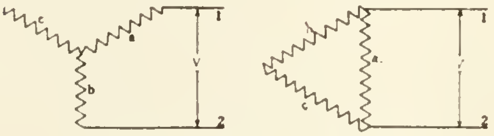


FIG. 870 (a) and (b)

871—Compounding of Rotary Converters by Setting of Brushes—Please give information regarding the setting of direct-current brushes on rotary converters. What is the proper method of setting these on, say, three new rotary converters, so that they will compound alike, and have the same power-factor at the various loads? I understand that changing the setting on one machine will change the compounding on all and cause sparking; is this so? We have three rotary converters in our power house that do not compound alike at all loads; can you suggest the reason and remedy? G. M. D. (N. Y.)

If the rotaries are duplicates they should have the same brush setting for operation at the same load. The ratio of alternating-current to direct-current volts and hence the compounding may be affected by a change of brush position. It is not good practice to effect compounding and load division between rotaries of different characteristics in this manner, owing to the bad commutation usually experienced when it is attempted. You should obtain an adjustment of power-factor and load division at all loads by changing the initial settings of the shunt field rheostat, by adjusting the series field shunt resistances and by inserting resistance in the equalizer connections where necessary. J. L. Y.

872—Efficiency of Pumping Systems—What are the relative merits and efficiencies of compressed air and direct driven pump system for sunken and deep well pumps? F. M. W. (MD.)

a—The reciprocating deep well pump will handle water free from dirt and grit satisfactorily from wells not over 500 or 600 feet deep, at an efficiency of not much over 75 percent., including the driving motor. Owing to the small size of cylinders which can be used, and the comparatively slow piston speeds necessary to avoid undue shock, only a comparatively small amount of water can be pumped. Also, this type of pump is limited to wells of not over six to eight inches in diameter. *b*—The turbine type of deep well pump will handle water not necessarily clear, at an efficiency of from 50 to 65 percent., including the electric motor. For lifts of over 150 feet this type of pump is seldom recommended, because of the heavy thrust on the pump due to the column of water above. Ordinarily, it cannot be used in wells of less than 10 to 12 inches in diameter. *c*—The air lift pump will handle clear or muddy water, but will not have an efficiency of over 20 to 30 percent., including air compressor, even under the most favorable conditions. It can be installed in wells of much smaller diameter than required for turbine deep well pumps, and for the most efficient operation the bottom must be submerged from one to one and a half times the lift from water surface to discharge. The turbine type pumps, of course, need only have sufficient water to cover them, and the reciprocating pump cylinders may even be 20 to 25 feet above the water surface. *d*—The air lift pump cannot be used in shallow wells, owing to the amount of submersion required, but for very deep wells, or wells which are very expensive to drill and which must be carried to considerable depth, the first cost of the air lift system and the fact that there are no moving parts beneath the ground surface, frequently make it the most economical installation. Also, if the conditions are suitable, the air lift will pump more water from a given sized well than any other known type of pump, but, of course, this will be at an increased power cost.

D. S. B.

873—Starting Induction Motor—We have a 120 hp, three-phase 40 cycle, 220 volt alternator for power and a 60 hp, 110 volt, direct-current, two-wire generator for lighting. These are at one end of the power house with steam engine, which also drives 150 hp of machinery, at the other end. All shaftings, dynamo and alternator are rope driven. It is intended to use corporation supply, 6 500 volt, 50 cycle, three-phase and keep our plant as a standby. It is proposed to install a 300 kw, 6 500 to 200 volt transformer to take the whole of the motor (present) load, and also the lighting; the star point to be used in the latter and the load balanced on all three phases. To save the price of a transformer, the 150 hp of machinery will be driven by a 150 kw, 6 500 volt, 50 cycle induction motor. This motor will stop about once every three months, it being one-half loaded two-thirds of its time. All this machinery has fast and loose pulleys. The motor would only have to start up with say 15 hp. *a*—Would a squirrel cage rotor work well and be preferred? *b*—What attention do these motors require when working and when stopped? *c*—What alternative voltage do you suggest and why; i. e., if another transformer be installed.

F. V. (ENGLAND)

a—A squirrel cage type of induction motor is preferable for applications involving infrequent starting, provided the starting conditions do not involve a torque which is beyond the pull-out torque of the motor as a limiting factor, or which does not require so great a starting current as to make its use objectionable from the standpoint of the source of power.

b—The motor should be erected upon a substantial foundation, located in a clean, dry, well ventilated, easily accessible place, free from acid fumes, steam, dripping water or oil, and excessively high external temperatures. The oil reservoirs should be filled with the best quality of dynamo oil, which should be occasionally replaced with fresh oil. The motor windings should be kept free from dust and grit by an occasional blowing out with dry compressed air at moderate pressure or with a hand bellows. *c*—The voltage adopted is satisfactory for plants of this size and is preferable in this case as the existing plant is 220 volts. The use of 6 500 volts on a motor of this capacity would be undesirable because the proportion of space required for insulation would be such that the design would not be economical. Any change in the voltage would require step-up transformers for the stand-by plant. In case of extensions the voltage adopted would be a function of the load and area of distribution. T. W. AND F. C. H.

874—Insulation Resistance of Alternator—Given a 5 000 k.v.a. 60 cycle, 11 000 volt generator, what would be considered the minimum safe insulation resistance of the stator after drying out, the insulation resistance, in the process of drying out, having attained its lowest value, and being on the ascendant. R. C. (MASS.)

The insulation resistance should be not less than one megohm per 10 000 volts used in the breakdown test. I. L. S.

875—Regulation for Inductive Load—We have two logging donkeys equipped with 150 hp 3-phase wound secondary motors. The service on these donkeys is very severe, a stalled position being very frequent. Hence, the voltage drop should be very small in this position. (Average all-day load, 700 kw-hrs.) We have a 625 k.v.a. steam turbine set. We also have a 20 ft. waterfall capable of developing, at low water, about 300 hp continuously. I propose to install a 400 or 500 k.v.a. water wheel set at these falls and run the 625 k.v.a. generator as an over-excited synchronous motor, and further to have an inductive load on the line to be switched off automatically when the logging donkey is thrown on. In this way the sudden load thrown on the generator would not cause the voltage to drop very much, as the low power-factor load of the starting motor would be balanced by the inductive load and the synchronous motor. This inductive load being on at times of no power output, would also balance the leading current of the synchronous motor, so the generator would not need to carry it. Would this scheme probably be successful and if so, what size and type of inductive load should be used? I. E. C. (IDAHO)

There is no reason for adding the complication and expense of the inductive load as proposed in this question. The same automatic means that would connect and disconnect this inductive load can be used to increase or decrease the excitation of the 625 k.v.a. steam turbine generator. In this way, the amount of leading k.v.a. supplied to the logging motors can be varied to suit the conditions of normal operation or otherwise. The field excitation of the steam turbine generator acting as a synchronous motor can be varied closely by means of a Tirrill regulator, or approximately by one or more switches that short-circuit sections of the synchronous motor field rheostat. F. D. N.

876—Burned Commutator Bars—We have two 22 kw, 6 pole, 176 ampere, direct-current generators working as exciters, in parallel, operating in connection with a voltage regulator at 125 volts at full load. The load is never more than 150 amperes each. What would cause the commutator bars to burn under the brushes, at three equidistant points on the commutators? From two to three adjacent bars at each place are affected. J. M. D. (ARIZONA)

Blackened bars on the commutator commonly indicate poor brush contact. This may be due to a rough commutator, either from high mica or high bars, and once started the burning action tends to spread. Any disturbance of one brush arm tends to set up a secondary disturbance at other brush arms of like polarity, and if the conditions are extreme this action will also be transmitted to brush arms of the opposite polarity. The commutators should be carefully observed to locate the point of initial disturbance and either ground or turned to remove he difficulty. Also, undercutting of the mica will tend to overcome this trouble, and is probably the easiest remedy in this case. R. H. T.

877—Operation of Exciters—(a)—Is it necessary to use compound-wound exciters in connection with a Tirrill regulator? (b) Will a compound-wound and shunt wound exciter operate well in parallel? (c) If a short-circuited band is placed between the two halves of a single shunt field, will it reduce the e.m.f. of self-induction when the field circuit is open, as for instance, by a Tirrill regulator? Will this copper band cause the field strength to respond slowly to changes in exciting current? (d) To what percentage of full-load current can the field current of a closed slot, heavily damped alternator be lowered before it will drop out of synchronism, and what would be the minimum percentage of a normal field current necessary to hold an open slot alternator, without dampers, in synchronism?
R. B. G. (CAL.)

(a) No, but compound-wound exciters are sometimes used because the series field winding supplements the regulator or, to express it another way, a slightly smaller shunt field current and therefore a smaller regulator is required with a compound-wound exciter than with a shunt machine. On the other hand the compound-wound exciter is more sluggish than the shunt exciter, so that the shunt exciter is generally preferred. (b) No. (c) If the copper band is around the poles, it will oppose any change of flux in the poles and therefore tend to make the flux change slowly, thereby reducing the e.m.f. of self-induction. (d) Ordinarily a very small field current, less than one-third normal, is required to hold an alternator in synchronism unless the line or engine conditions are unfavorable to parallel operation. We know of no comparative experiment to determine the difference between the two types of alternators mentioned. In any event the value of field current in any particular case would have to be determined experimentally.

878—Torque of Wattmeter Disc—(a) Is there any formula, empirical or otherwise, for calculating the torque exerted on the aluminum disc of a wattmeter by the retarding magnets? (b) Does a variation in temperature affect the retarding force to any appreciable extent? (c) What difference in operation is obtained when a thick disc is used? When a thin one is used?
J. F. K. (N. Y.)

(a) We know of no formula, used in practice, for the calculation of the torque exerted on the rotating disc of a watthour meter by the magnets. This torque is determined by experiment. (b) In general, variation in temperature affects the retarding force, as the resistance of the disc is increased or decreased. In watthour meters of the induction type, where the driving or electro-magnet and the dragging or permanent magnet act on the same disc, a change in the resistance of the disc has little or no affect on the speed. In direct-current watthour meters, where the disc is used only for drag purposes, the temperature effect on the disc has to be taken into account. Compensation, in cases where aluminum discs are used, is generally obtained by the use of copper resistance in the shunt circuit, as copper and aluminum have about the same temperature coefficient. An increase in temperature would tend to increase the shunt circuit resistance and decrease the shunt circuit current, thus decreasing the driving torque of the armature, which would tend to counteract the decreased drag torque resulting from the increase of disc resistance.

(c) For a given torque, the thicker the disc the weaker the magnets required. The ratio of the torque to the weight of the moving element should be maintained as high as practical, so as to reduce friction errors to a minimum. In view of this the disc is generally made thin and light.
C. R. R.

879—A Commutation Problem—We have two similar motor-generator sets with direct-current non-interpole, shunt wound generators, rated at 357.5 kw, 14 poles and brush arms, 485 r.p.m., 168 volts, 2125 amperes [illegible] to brushes per arm, brush cross-section 1¼" by 1", diameter of commutator 28.5 in. These generators run at 2800 and 3000 amperes continuously. After trying several types of brushes, we found that a carbon brush with seven strips of copper gauze running across the commutator is the only kind that will commutate properly. The objection to the use of this brush is that it wears away the commutator too rapidly. According to the manufacturers' drawing, the commutator diameter was 28.5" when new (1907). Recent measurements are as follows: 1910, 27.9"; 1911, 27.6"; 1912, 27.2". What will limit the life of commutator, mechanical strength or heating? How thin will we be able to wear the commutator? We have recently tried a soft carbon brush. Both commutator and brush-face had a good polish, but got very hot, and brushes chattered so much that we took them off. The brush people said that the trouble was due to high mica and that the copper gauze kept the mica worn off even with the copper, and that the heat was due to friction caused by high mica. They advised us to under-cut the mica and use a soft brush to lengthen the life of the commutator. Would high mica cause heating with no sparking? Would you advise under-cutting? What apparatus could be used for undercutting without removing the armature from the field?

O. R. S. (W. VA.)

The commutators can probably be worn down to a diameter of about 26 inches, hence if the rate of wear remains the same as during the past five years, their total life will be about eleven years. The limit of the life of commutators is mechanical strength and not heating. The commutators may be worn down until they begin to show roughness at the outer end due to springing of the commutator bars from centrifugal forces. A paraffine lubricant used with the copper gauze brushes will probably reduce the amount of wear. High mica, if it exists, will cause heating, probably due to sparking under the brushes which may not be very noticeable. Undercutting the commutator will probably be all right if the generators are kept reasonably clean. This undercutting can be done with a hand tool made out of a hack saw, or there are several special tools for accomplishing the same purpose. It can be done without removing the armature. See also article on "Care and Operation of Commutators," by Mr. W. A. Dick, in the JOURNAL for May, 1912, p. 378. D. H.

880—Testing Gas Engines—We are desirous of testing 65 hp gas engines, the load to be a three-phase induction motor, the motor starting the engine, then the engine driving the motor above synchronism of the factory mains. (a) Would a 65 hp induction motor be of sufficient capacity? (b) How much above synchronism (60 cycle supply) would a standard motor have to be driven? (c) What effect would a change of speed have on the "induction" generator output? (d) What would be a simple and accurate switchboard equipment for the above testing set? (e) Would the hp delivered by the engine be $\frac{\text{kw output}}{0.746 \times \text{motor eff.}}$ (f) How would the motor "loading back" effect the power-factor of the line? (g) Is there any objection to using this method of obtaining an accurate testing load? (h) Is not this method preferable to prony brakes, water rheostats, etc., inasmuch as it effects a saving at the meter by helping out on the factory load? B. H. D. (CAL.)

(a) A 65 hp motor would be satisfactory, provided it had the same overload capacity as the gas engine. (b) The motor will exert a counter torque when driven above synchronism at a certain negative slip, which is approximately the same as its motor torque when running at the same slip below synchronism. In other words, if the motor has four percent slip when running as a motor and delivering 65 mechanical hp, it will deliver approximately the equivalent of 65 hp as a generator when driven at 104 percent of synchronous speed. (c) Assuming the frequency of the supply circuit to be maintained normal, if a squirrel cage motor were used, it would be necessary to have the speed of the gas engine such that the induction generator would have exactly the right negative slip to give the desired load. If a wound rotor induction motor were used, resistance could be inserted so as to give a certain negative slip for a given torque just as resistance may be inserted in a motor circuit to decrease the speed under a given load. This would have the drawback that power would be lost in the resistance in proportion to the total power generated almost in the percentage that the operating speed varied from synchronous speed. (d) The switchboard should contain a suitable oil circuit breaker which may be combined with the starting device if a squirrel cage induction motor is used and should have a polyphase indicating wattmeter with a scale of about 20-0-80 kw to show whether the machine was working as a motor or generator. (e) This statement would be true if all conditions as regards speed, etc., were correct. (f) Whether running as a motor or a synchronous generator, the induction machine would in any case draw its magnetizing current from the line. This current may run as high as 30 or 40 percent of the full load current of the motor, so that this amount of wattless current is added directly to the wattless component, being drawn from the supply circuit with consequent reduction in power-factor. (g) Considered solely from the standpoint of testing the gas engine, it would seem that this scheme is possible and could be worked out satisfactorily. (h) Taking into account all the features of this proposed scheme it would seem to be practicable, but in many ways to be less desirable than a corresponding scheme for "loading back" a direct-current generator on a direct current circuit. In this connection, see "Automobile Engine Testing by Electric Motors," by Mr. A. G. Chapin, in the JOURNAL for November, 1912. A. M. D. AND S. Q. H.

881—Synchronizing Alternators—Is it practical to connect a 750 kw generator to a 1 500 kw system as follows: Bring the generator to synchronous speed with both field and main switches open. Close the main switch and an instant later the field switch. Is there a possibility of the field poles being of the wrong polarity after the field switch is closed? R. E. C. (CAL.)

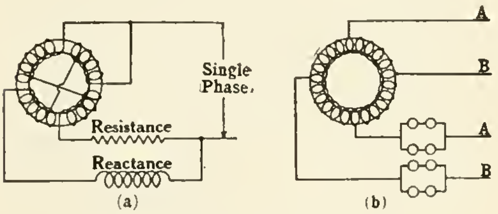
The generator with main switch closed and field switch open will be operating as an induction motor or generator, depending on its speed. When the field switch is closed, the generator must be brought into exact synchronism, if it was not so operating, and the field excitation into correct relation with the field set up by the armature winding, if this condition did not happen to exist when the field switch was closed. Both of these adjustments may mean a large armature current, which can easily be objectionable. If the field is excited directly out of phase, the armature current will have to be sufficiently large to give double the normal field ampere-turns. Whether this is a momentary of steady condition depends on whether the design of the generator permits it to slip a pole when the main switch is closed. It is evident from the above that it is not practicable to connect a generator to another generator, as proposed in the question, without synchronizing. F. D. N.

882—Why is a vacuum measured in inches? O. M. (IDAHO)

A vacuum is ordinarily measured in inches of mercury, simply because this is the most convenient and accurate method. It could be measured in feet of water, if desired, but in this case the gage would have to be over 30 feet long. When an ordinary pressure gage is used to measure vacua, it could be calibrated in pounds per square inch, or in any other way desired, but such gages are always calibrated against a mercury tube as a standard, and hence it has become customary to refer to all vacuum measurements in terms of inches of mercury. C. R. R.

883—Demonstration of Rotating Magnetic Field—(a)—Is it possible to demonstrate a rotating magnetic field with single-phase current by using a round coil with a piece of glass laid over it so that small pieces of steel will tend to travel around the coil on top of the glass, based on the principle used in starting single-phase induction motors? Please indicate the necessary amount of wire and iron and the arrangement. (b) If this is not possible, please state the dimensions for connecting to two-phase 440 volts with lamps in series. E. E. M. (IND.)

(a) It is possible to show the rotating magnetic field by the use of single-phase current by means of a teaser coil or phase splitter, as shown in Fig. 883 (a), the coil being wound around a laminated iron core as indicated. Since this device cannot give a complete quadrature relationship between the main and derived currents, more power will be required to produce the desired effect. (b) The best arrangement will be to use the two-phase current if available, arranging a laminated iron ring about 6 or 8 inches in diameter, one square inch section, or larger, if desired; wind this with two layers of No. 20 d.c.c. copper wire and connect as shown in Fig. 883 (b), with sufficient lamps or other resistance in the circuit to produce the desired magnetic strength. A very effective demonstration is produced by "blowing" an egg, covering the shell with plumbago and copper-plating it with a fairly heavy covering. When placed on the plate over the laminated ring, such a plated egg will spin on end. Similar results can be obtained with a hollow metal ball or top, while a common brass washer, if started rolling around the plate, will continue to roll indefinitely in a circular path. If it is not desired to wind a coil specially for this purpose, the stator of a small induction motor, either single-phase or polyphase, can be used by removing the rotor and end frames. Ordinarily it is necessary to place a resistance in series in order to limit the current. P. T.



FIGS. 883 (a) and (b)

884—Reaction in Shunt Wound Direct-Current Generator—What is the reaction which takes place in a direct-current shunt generator, if, when at rest, the leads to the field coils are reversed; the machine is then started up again with direction of rotation and position of brushes remaining the same? J. W. G. M. (ENGLAND)

After the change as above described is made, the generator will not build up its voltage. A generator depends upon residual magnetism to start to build up the voltage, hence, if the field winding is so connected that as soon as the voltage starts to build up, the magnetism produced by the field excitation opposes the residual magnetism, a condition of zero magnetism is then obtained and the voltage will not build up. Even though the field is "flashed" from a separate direct-current source, the machine will not generate voltage if the connections are so made that the polarity of the brushes causes current to flow through the field in a direction tending to oppose the residual magnetism and reduce the magnetism and voltage to zero. J. M. H.

885—Motor-Generator Set for Telephone Exchange — The direct-current motor generator set in a telephone exchange consists of two one-half hp machines, the motor being wound for 220 volts and the generator for 45 volts. Both armatures have the winding tapped at the commutator just one bar less than half way around, the taps being taken to slip-rings at the rear of the armature to get single-phase current for ringing the telephone bells. As the set runs at 1 200 r.p.m., the 220 volt machine, which has two poles, delivers 20 cycle current, and the 45 volt machine having six poles delivers 60 cycle current, the alternating current from both machines passing through separate transformers to get the desired voltage. The machines are convertible, that is, the 45 volt machine can be run from the storage battery, and the 220 volt machine has a generator, exciting its own field; also the 45 volt machine excites its own field when it is run as a generator. Alternating current is taken from both machines at all times. When the 45 volt machine was running as the generator, it refused to pick up its voltage unless the field was excited from some outside source. The armature and field coils were tested and found to be in good condition, the fields having a resistance of 60.6 ohms, or, 10.1 ohms per field. With the alternating-current load disconnected, the machine would pick up, but as soon as the load was on, the machine lost its field excitation. When the fields were separately excited from the battery, the generator voltage was maintained, but when the alternating-current load came on both machines simultaneously, they would slow down in speed, with a resulting drop in voltage, the brushes being set on the exact neutral point. With a lighter load, no trouble whatever exists. My theory is that the alternating-current robbed the fields of the current necessary to properly excite them and thus the residual magnetism of the machine was killed, but when the machines were run from the battery, the battery current kept the fields excited. Is my theory correct, or should there be some other explanation?

E. J. F. (ILL.)

When the motor generator set is being driven from the 220 volt machine, the 45 volt machine is acting as a double-current generator. In such a generator the alternating current and the direct current have the same direction in the armature windings. From all indications this generator operates at a point too low down on the saturation curve. If a low voltage direct-current self-excited generator such as this operates some distance below the knee of the saturation curve, the voltage would be liable to fall off entirely as the load came on, and especially under very heavy loads. This is due to the fact that the lower part of the saturation curve approximates very closely a straight line, where the field excitation is directly proportional to the voltage. When the load comes on the main field flux is distorted and weakened somewhat, due to the effect on it of the flux due to the armature ampere-turns. This lowers the induced voltage, which in turn decreases the field excitation a proportional amount, the weakened field lowering the voltage altogether. On the other hand, if the generator works normally at a point on the curve close to the bend, when the induced voltage falls off a little due to the armature reaction the field excitation does not fall off proportionally, and therefore the voltage will drop to a certain point and remain there. When the generator carries the direct-current load alone, it is evidently lightly loaded, so that the armature ampere-turns are low compared to the field ampere-turns. When, however, the alternating-current load is put on, the armature ampere-turns increase in proportion until the field distortion is noticeable, to the extent that the voltage falls off as mentioned. If the generator was heavily loaded on the direct-current side only, the effect would be the same. There are two ways that the trouble could be corrected. The simplest would be to separately excite the generator from the storage battery, or from the source of the 220 volt supply with sufficient resistance in series with the field to lower the voltage across the field to the normal amount. The second plan is to work some part of the magnetic circuit at a higher flux density. For instance, if there are liners behind the main poles, which have the same cross-section as the pole body, these could be cut down so that the section of the part of the flux through the liners is small enough to be pretty highly saturated. Then the saturation curve of the generator will start to bend at a lower value of the flux than formerly, and if the size of the liners is decreased the correct amount, the point at which the machine operates on the curve can be made to come close to the bend. How much to cut off the liners could only be calculated if the constants and dimensions of the generator are known. The first method is simpler, and generators of fifty volts or less are generally designed to be separately excited. With the second method stronger field coils might be needed, depending on how much margin there is in the coils at present on the generator.

C. G. L.

886—Spotting on Commutator of Commutating-Pole Generator—Twelve distinctive spots covering two to five bars have developed on a six pole, 175 kw, 500-600 volt commutating-pole generator which we are operating, although the machine is not overloaded. The spots are located symmetrically around the commutator with a spacing corresponding to one-half that of the six sets of brushes. Growth of the trouble has been prevented only by continued sandpapering. After trueing the commutator by means of an emery wheel grinder, the trouble disappears entirely for a day or so. Please suggest cause and remedy of trouble. Is it possibly caused by reversed armature leads?

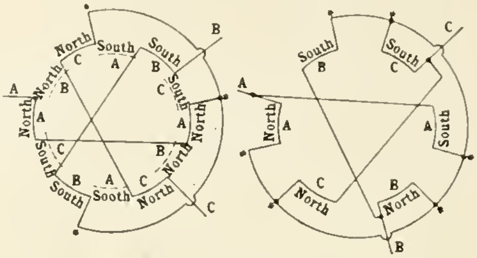
W. C. M. (KAS.)

As there are 12 marked points on the commutator which are equally spaced, it may be possible that only four cross connecting rings are used on this winding (we are assuming this is a parallel wound machine), and if such should prove to be the case, we would advise that the number of cross connections is too small, as the marking of the commutator would correspond exactly to the taps from the cross connection rings to the commutator bar. In this event the cure would be to increase the number of cross connectors. See also No. 876, this issue.

887—Connections for Two-Speed Induction Motor—Will you please give diagram or explain manner of connecting a three-phase, 60 cycle, six coil induction motor for synchronous speeds of, respectively, 1 800 and 3 600. Explain how with six coils, and two diammetrically opposite coils per phase (either in series or parallel), four poles are established.

T. L. M. (MEXICO)

The connections for four poles and two poles are shown in Figs. 887 (a) and (b), respectively. It should be noted that six coils are only enough for two poles, three phase, with ordinary connections, but when the two coils in phase A are both connected for north poles, for example, two consequent south poles are formed half way between these two north poles. Thus Fig. 887 (a) represents the connections for a four pole motor of *n* horse-power, and Fig. 887 (b) connections for a two pole motor of *2n* horse-power. The reason the groups are in series on the low speed and in parallel on the high speed is because approximately twice as many turns are required for the necessary founter e.m.f. on the low as on the high speed.



FIGS. 887 (a) and (b)

A. M. D.

888—Paralleling Alternators—Please explain why, if two direct connected engine-driven alternators are synchronized or connected to the bus-bars when slightly out of phase, current will surge from one machine to the other for hours and sometimes all day. I have always thought that this was caused by the governors of the engines pumping back and forth, as I understood the tendency of alternators is to draw into phase and stay there. I have often seen operators after synchronizing, open the switches and phase in again when they made a poor phase in the first place.

L. A. F. (MASS.)

If poor synchronizing results in continued hunting, the generators must have very little damping capacity, or the natural period of the generators must correspond very closely with the impulses transmited by the engine. It is true that alternators tend to draw into phase and stay there, but the coincidence of generator natural periodicity and engine impulses or conditions in the engines, governors, etc., that tend toward hunting, may cause the phenomena described in the question. In some cases, with engines of equal speed, the hunting may be apparent when the machines are in parallel, with the engine cranks not in phase with each other, while the hunting may disappear when the machines are paralleled with the cranks in phase.

F. D. N.

889—Design of Transformer for Wireless Telegraphy—I have the complete design worked out for a one kw, 60 cycle, 110 to 20 000 volt step-up, closed core wireless transformer. What simple rule applies to changing the design as regards, for instance, a change to 110 volts, 30 cycles or 110 volts 120 cycles? For a change to 30 cycles from 60 cycles, what approximate rule would apply as regards the cross section and length of the iron core? How about the primary winding and also the secondary 20 000 volt winding? I presume, other things being equal, that the primary current for 110 volts 30 or 120 cycles, would be the same approximately as for 110 volts 60 cycles. Is this correct? What is the efficiency of a one kw open core transformer of good design with the above voltage ratios? H. W. S. (NEW YORK)

The induction in the core for a given voltage and number of turns is inversely proportional to the frequency, therefore, if the induction and voltage are maintained constant, either the area or the number of turns or their product must be increased in inverse proportion to the frequency. A good rule to follow is to increase both the area and the number of turns inversely as the square root of the frequency, and keep the proportions of the core the same. If the same core is to be used for 30 cycles as for 60, approximately double the number of turns of finer wire may be used, and a transformer obtained of lower output. To obtain the same results at 30 cycles as at 60 cycles will require the same amount of power, but this capacity required will be greater at the lower frequency. The efficiency of a good commercial 22 000 volt, one kilowatt transformer, at full load, should be about 85 percent.

C. F.

890—Make-Shift Motor Starter—If an auto-starter for a 50 hp, three phase, 220 volt squirrel cage motor becomes damaged, could I use a water rheostat in each line for starting until the auto-starter is repaired? J. R. A. (GEORGIA)

A water rheostat would be entirely satisfactory for emergency starting, if of sufficient current carrying capacity and having sufficient resistance. Only two rheostats would be necessary, one in each of any two of the three phases. C. R. R.

891—Power Rate for Electric Spot Welding—We would like to learn of some equitable tariff for electric spot welders. We have been informed that some power companies charge on a kw-hour basis at five or six cents per kw-hour, but as the duration of the welding operation is short, the power consumption cannot be measured accurately, owing to the lag of the meter. Also, assuming that all of the current consumed is measured, the return from this method of charging does not seem adequate to cover fixed charges on the large capacity of equipment necessary to supply energy for these machines. The regular flat rate for motors based on installed capacity of machines, seems to be too large.

H. J. G. (ONTARIO)

One large company who have quite a heavy load in spot welders charge the following rate for this type of service:

> Less than 100 hours, monthly use, maximum demand, 1.5 cent per hp-hr.; 100 to 200 hours monthly use, maximum demand, 1.25 cent per hp-hr.; 200 to 300 hours monthly use, maximum demand, 1.125 cent per hp-hr. Over 300 hours use—1 cent per hp-hr.

This company finds it very desirable to install a meter of approximately 20 percent. of the rating of the spot welders. When a meter of approximately the same rating is used, the momentary load is not registered, and even when using a meter of approximately 20 percent. rating, the meter only registers, as near as they can estimate, about 40 to 50 percent of the total power. The officials of this company feel that the power which is supplied for spot welders at the above rate is at a loss, because it is impossible to secure a correct registration. Another large power company charges $3.00 per kilowatt of maximum demand per month, [illegible] of a cent per kw-hour for energy used. This seems a much more equitable rate, as we believe the rate for this type of intermittent service, which requires large capacity in transformers and lines, and produces severe fluctuations of voltage, should be based almost entirely on a demand rate. In this way the large investment necessitated on the part of the central station secures a reasonable return, which is not possible with a straight kilowatt-hour rate, as the total power consumption from spot welders is comparatively small in most cases. S. A. F.

892—Transmission Line Condenser Effect—The company with which I am connected operates a 350 mile, 60 000 volt transmission system. The charging k.v.a. is about 2 800, and the total generating capacity is 15 000 kilowatts. Considerable difficulty is encountered in holding the frequency and voltage normal at the receiving end of the line at no load, apparently on account of the condenser effect of the line. Would it not be possible to operate part of the generating equipment as synchronous motors, thereby making the power-factor of the system unity, and neutralize the condenser effect of the line? R. B. G. (CAL.)

The condenser effect of the line has no effect whatever on the frequency, which is dependent solely on the speed of the generators. If the voltage becomes too high at the receiving end of the line, a synchronous motor, or an idle generator running as a synchronous motor, at the receiving end could be operated with low field excitation to improve the power-factor and counteract this tendency. A large induction motor would be equally satisfactory, except that the power-factor in that case would not be adjustable. A stationary inductance would also satisfy the conditions and would be very much cheaper in case any additional apparatus had to be purchased. For detailed information on the use of synchronous motors for power-factor correction, see the JOURNAL for October, 1911, Vol. VIII, page 943.

893—Bearing Lubrication—What results will be obtained if an oil ring in a 10-inch bearing is replaced by an iron or steel chain. R. B. G. (CAL.)

A chain is much more liable to stick and stop rotating than is a solid ring. Chains were generally used a good many years ago, but have been practically abandoned for this reason. E. M.

894—Long vs. Short Shunt Connection—What is the relative value of long or short shunt connection in a motor or a generator? H. R. S. (PA.)

Long or short shunt field connection is almost entirely a matter of preference and is settled as most convenient for the manufacturer. For a generator, the short shunt connection causes the shunt field to assume a larger proportion of the full-load excitation than for long shunt. The former is, therefore, desirable if the series tends to overheat. A reduced series drop, as obtained by short shunt connection also means operating at a slightly lower point on the saturation curve, which corresponds to a regulation curve with less "hump" between no load and full load points. For a motor, it is commonly desirable to have the shunt field and armature circuits entirely separate, particularly where the machine is to operate in either direction, so that the main switch or circuit breaker will not open the field. Long shunt is, therefore, the customary method of connection for motors. R. H. T.

CORRECTIONS

March Issue—In the title to Fig. 5 on page 233 of the March issue, the words "double-action" should read "double-suction." In the line below the word "large" should be omitted. Near the bottom of page 250, the efficiencies should read: "0.50 for steel plate fans, 0.65 for Sirocco fans and 0.45 for cone type fans." On page 224, second line under the cut, "75 horse-power motor" should read "7.5 horse-power motor."

February Issue—On page 152, the 12th line from the bottom, to the phrase "the only satisfactory method is by drop of potential," add "or by the use of a potentiometer." On page 154, the second line should read: "consists of a potentiometer whose scale is calibrated directly in degrees."

PERSONALS

Mr. Horace H. Esselstyn, engineer for Westinghouse, Church, Kerr & Company, at Detroit, Mich., has resigned to become construction engineer with the Detroit Edison Company.

The Transmission Company has been organized in Pittsburgh to do special transmission line work. It is coöperating with the Railway & Industrial Engineering Company, manufacturers of the Burke horn gap apparatus, and is making a specialty of steel outdoor substations and crossings, and similar requirements. The officers are Mr. H. L. Patterson, president; Mr. G. N. Lemmon, vice president and general manager; Mr. B. W. Kerr, secretary-treasurer, and Mr. A. W. Burke, consulting engineer.

Mr. Raymond J. O'Brien, formerly of the railway engineering department of the Westinghouse Electric & Manufacturing Company, has resigned to accept a position with Messrs. Gibbs & Hill, consulting engineers, of New York City.

PITTSBURGH MEETING—A. I. E. E.

A meeting of the American Institute of Electrical Engineers will be held in Pittsburgh, Pa., April 18th and 19th, 1913, under the auspices of the committee on the Use of Electricity in Mines, Mr. Geo. R. Wood, Chairman, in coöperation with the Pittsburgh Section. Headquarters will be at the Fort Pitt Hotel.
The program is as follows:

FRIDAY, APRIL 18TH

9 A. M.—Registration, Convention Headquarters.

10 A. M.—Opening address by President Ralph D. Mershon. 1. Paper by Mr. H. C. Eddy, American Gas & Electric Company, "Purchased Power in Coal Mines." 2. Paper by Mr. J. S. Jenks, West Penn Traction and Water Company, "Central Station Power for Mines." Discussion. 3. Paper by Mr. H. H. Clark, Bureau of Mines, "Safeguarding the Use of Electricity in Mines." Discussion.

2 P. M.—4. Paper by Mr. J. W. Hopwood, United Coal Company, "Electricity as Applied to Mining." 5. Paper by Mr. C. W. Beers, Lehigh Valley Coal Company, "Central Station Power for Coal Mines." 6. Paper by Mr. F. B. Crosby, General Electric Company, "Alternating-Current Motors for the Economic Operation of Mine Fans."

6 P. M.—Dutch dinner at Fort Pitt Hotel. Informal exercises will be brief and will conclude at 8 o'clock, so that the remainder of the evening will be at the disposal of those desiring to make other arrangements.

SATURDAY, APRIL 19TH

10 A. M.—7. Paper by Mr. H. M. Warren, D. L. & W. Railroad Company, "Characteristics of Sub-station Loads at the Anthracite Collieries of the Delaware, Lackawanna & Western R. R. Co." 8. Paper by Messrs. Wilfred Sykes and Graham Bright, Westinghouse Elec. & Mfg. Company, "Mining Load for Central Stations. 9. Question Box—This is to afford a means for interesting topics for discussion by those who do not care to participate in person. The Chairman will read the questions and request various persons in the audience who are best qualified, to answer them.

WESTINGHOUSE BANQUET

The third annual banquet of The Westinghouse Club was held at the Hotel Schenley, Pittsburgh, March 8th, with an attendance of about 600. Mr. Charles A. Terry, vice-president of the Electric Company, who acted as toastmaster, was introduced by Mr. E. M. Herr, president. The other speakers were: Mr. H. H. Westinghouse, president of the Westinghouse Traction Brake Company; Col. H. G. Prout, vice-president and general manager of the Union Switch & Signal Company; Mr. E. S. McClelland, chief engineer of steam and gas engine departments of the Machine Company; Mr. Robert Garland, of the Pittsburgh City Council; Mr. Guy E. Tripp, chairman of the board of directors of the Electric Company; Mr. E. A. Craig, southwestern manager of the Air Brake Company.

NEW BOOKS

"Hygiene for the Worker," Wm. H. Tolman & Adelaide Wood Guthrie. 225 pages. Illustrated. Published by the American Book Company. For sale by the ELECTRIC JOURNAL. Price 50 cents.

While this book is written as a text for elementary school work it can to advantage be read by those interested in various lines of industrial work. It contains much valuable advice with reference to personal habits as well as life in the work rooms.

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BY this we mean the Hide Faced Hammers and Mallets have been made by us and are ready for the consumer.

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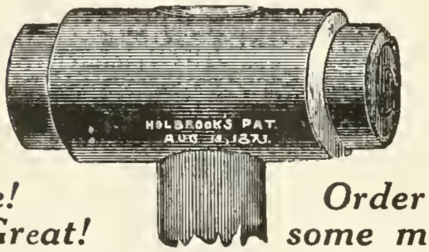

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NEW BOOKS

"Steam Boilers"—E. M. Shealy, 350 pages, 184 illustrations. Published by McGraw-Hill Book Company. For sale by the ELECTRIC JOURNAL. Price, $2.50.

A book prepared to provide a working understanding of the steam boiler, in which effort the author has admirably succeeded, should find a useful place in both large and small boiler rooms. The subject matter has been presented in the simplest possible form, making it easy to be grasped by the non-technical operator, which conforms with the original idea of the author obtained by direct contact with the need which became evident through correspondence teaching in the Extension Division of the University of Wisconsin. All sizes of boilers commonly found in practice are properly described and their principal features set forth. This is followed in subsequent chapters by a light treatment of boiler plant auxiliaries and accessories, including the boiler chimney. A separate chapter is given over to important boiler calculations, and also details appertaining to stays and staying, information regarding which is vital to the safety of operation. The author takes up also the physical properties of steam, the classification and handling of various fuels, the chemistry of combustion, principles of firing, settings, general care, operation, test and inspection of boilers. E.D.D.

"Elements of Heat Power Engineering"—C. F. Hershfeld and W. N. Barnard. 800 pages, 480 illustrations. Published by John Wiley & Sons, New York. For sale by THE ELECTRIC JOURNAL. Price, $5.00.

This book fundamentally takes up the theoretical phase of the generation of power from heat and interestingly coördinates numerous practical considerations. The first ten chapters are devoted to the thermodynamic theory of heat and heat energy and the laws of gases. The authors take up at length in independent chapters, the various features of a steam engine and accessory parts and also the turbine and internal combustion engines. A particular valuable feature is the inclusion of basic formulæ and equations applying to the several parts of the heat power plant, which should lead to a better understanding of the performance of the equipment. It is not a part of the scope of this book to embrace any matters of mechanical design. E. D. D.

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Selection of Transformers for Three-Phase Circuits

The question as to whether to use a three-phase transformer or three single-phase transformers is one which comes up frequently, and definite information is lacking as to which type of installation is the best in any given case. The article in the present issue, by Mr. William Nesbit, entitled "One Three-Phase vs. Three Single-Phase Transformers," points out the relative advantages and disadvantages of single-phase and three-phase transformers, comparing their first costs, efficiencies, floor space, weights and ease of operation and repairs. While no infallible general rules can be laid down governing the proper choice, yet certain points are presented for consideration which indicate the best type to use under given local conditions.

A summary of the situation seems to show that for the operation of a single rotary converter or motor-generator set the three-phase transformer has well-defined advantages. In general distribution work, however, where a market has to be built up, the single-phase lighting load is usually developed first, being the easiest to obtain. One single-phase transformer may, therefore, be used to supply this load and later if the load increases to a value above the rating of the transformer installed, another single-phase transformer may be added, the two being connected in open delta so as to better distribute the load over the phases of the transmission system, and which will provide for the taking on of power contracts requiring three-phase power. Later as the combined load grows, still another single-phase transformer may be added, completing the delta and increasing the rating of the transformer bank from 58 to 100 percent of the combined capacity of the three transformers. In some cases where the market exists already for both lighting and power, it might even be advisable to install two transformers connected in open delta, of sufficient capacity to take care of the present market, and reserve the addition of the third transformer, completing the delta, to take care of future growth.

A. P. Bender

A New Development in Direct-Current Generators

An entirely new engineering development is described in this issue of the JOURNAL in the article by Mr. David Hall, entitled "Large Turbine Driven Direct-Current Generators." For a considerable number of years the steam turbine and the alternating-current generator has been the subject of careful study and development, until we now have units of exceedingly large capacity and remarkable economies. These units have kept pace with the rapid demand for generators and prime movers of increasingly large capacity to care for the remarkable growth of electric power and railway systems. During this time, however, direct-current generating apparatus has continued to be confined to the slow speed type suitable for direct connection to reciprocating units, or in moderate sizes to units driven by motors in the well-known motor-generator sets. The advent of the reduction gear, making possible the application of steam turbine drive to direct-current generators, represents a remarkable achievement and opens a field of vast possibilities for the utilization of direct-current generating apparatus. By this means it is now possible, as the article indicates, to build successfully direct-current generators of capacities that were impossible a few years ago. The interposition of the reduction gear between the high-speed steam turbine prime mover and the necessarily slower speed direct-current generator offers an elastic buffer that permits the utilization of the most desirable speeds on both the turbine and the generator, since the speed reduction ratio through the gear is very flexible and covers wide limits.

The application cited in Mr. Hall's article is unique, but this is only one of many applications where such units could be installed to advantage. The low pressure steam turbine, used in connection with the reduction gear and generator, offers possibilities for direct-current generation in large units at economies that could not be approached prior to the advent of this combination unit. The suggested utilization of two steam turbines driving one gear connected to two generators in tandem indicates the remarkable possibilities of this combination and demonstrates that direct-current generating units can now be obtained in practically any capacities that may be desired, while with the old type reciprocating engine unit the largest capacity that could be manufactured successfully was reached several years ago, and there has been practically no advance in the meantime.

E. P. DILLON

The New Shop Testing Series

Those who have had experience in the testing departments of large operating or manufacturing companies realize that they have had an opportunity to gain an insight into the characteristics and operation of electrical machinery which would have taken them many times as long to acquire in the ordinary operation of apparatus. In power plants the machines are permanently connected up, and the routine work of starting and stopping the machinery can, in many cases, be carried on by men who may not even know the connections involved. The successful tester must know how to connect up various types of apparatus, must know how machines should operate under normal conditions and how to tell instantly if there are any defects or incorrect connections present. There is a certain fascination in testing generating apparatus which has never been in operation before, in seeing the aggregation of copper, steel and insulation begin its life work of producing electric energy. Engineering students are thus usually intensely interested in testing methods.

In the first issue of the JOURNAL, in February, 1904, was begun a series of articles entitled, "Factory Testing of Electrical Machinery," which was continued until October, 1905. These articles were received with marked favor and have been used quite generally as a reference text for the last eight years. Reprints have been made, but these are now exhausted, and it has been deemed advisable to publish a new series. In the period since the publication of the first articles there have been many changes in the design of electrical machinery, as well as improvements and refinements in testing methods. In the articles on "Shop Testing of Electrical Apparatus" appearing in the present volume, it is aimed to include all of the good features of the old articles and, while bringing them up to date, to incorporate new ideas and the experience gained in the last eight years. Owing to the wide scope of the articles, it was not feasible nor desirable to rely on any one individual for this material, and the articles as published represent a compilation of the best ideas and methods of a number of expert testing engineers.

The descriptions of the various methods have been so classified that all the information necessary for the carrying out of any particular test is conveniently available. It has been the aim to explain each operation in such a way that those who have not had actual testing experience will be able to understand each step and the reason therefore. Although the testing methods described represent in the main (as any complete description of the tests of a large variety of apparatus must) the methods in common use in a large manufacturing concern, the needs of the tester in small shops or college laboratories have not been over-looked. In the large concern, where tests are continually being made on a commercial basis, the testers are provided with every facility for making tests accurately and in the shortest possible time. It is natural, therefore, that tests which are made under such conditions may not be feasible where the equipment is inadequate or where testing is rarely done; on the other hand such tests may not be sufficiently refined for special conditions where time and expense are not so important. Where more than one method of testing is in common use, the different schemes are given, along with a description of the requirements and limitations of each.

The importance of accuracy in testing to builders of electrical apparatus can hardly be over-estimated. Their reputations depend on their ability to supply machines which will prove uniformly satisfactory in service, and this can only be assured by proper testing. Of equal importance is the fact that a considerable part of design data is empirical and based upon test results obtained from machines previously constructed. Upon the accuracy of such tests, therefore, depends the correctness of future designs.

In commercial testing it is the aim to reproduce actual operating conditions. In the case of very large machines, full-load tests are impracticable, as no concern can afford to maintain testing equipments involving such large amounts of power, as well as heavy foundations, etc., for various types of equipments. Substitute or loading back methods are therefore employed to reproduce, as nearly as may be, the desired conditions. When it is impossible to secure the exact conditions, it is important to know the discrepancies involved, and the determining of these often involves considerable study and investigation. Various methods of securing approximate load conditions are described in these articles, with the advantages and limitations of each.

The present series, as already outlined, is to continue throughout the year and probably into the next volume. It is hoped that it will be of even more value than the original articles, which have proven so helpful to many young engineers in securing definite and practical information on this very interesting subject.

ONE THREE-PHASE VS. THREE SINGLE-PHASE TRANSFORMERS

WILLIAM NESBIT

THE greater reliability of the latest types of transformers makes desirable the more general use of the three-phase type. Heretofore the principal reason for favoring the use of three single-phase in preference to one three-phase transformer has been the ability to carry nearly two-thirds of the three-phase load on two of the single-phase units, should the third unit be disabled. Transformers can be, and are now being manufactured which are more reliable than the rotating apparatus which they feed or which feeds them. For instance, a transformer feeding a rotary converter receiving its current from an underground transmission system is much less likely to cause a shutdown than is the rotary converter itself. It would seem in such cases about as justifiable to consider a spare rotary converter as spares in static transformers.

IMPROVEMENTS IN TRANSFORMERS

Designing engineers have not been overlooking the causes of past difficulties, many of which are now quite well understood and are guarded against in the design and manufacture of present-day transformers. Many transformer failures in the past have been due to the presence of moisture in the oil or the absorption of moisture by the transformer during shipment, or at destination before being immersed in oil. This source of trouble has been effectively overcome by means of the vacuum method of drying transformers, after which they are immediately immersed in oil and ready for shipment. This method of shipping the transformers sealed up in their tanks with oil is used by one large manufacturing company on all sizes up to about 5 000 k.v.a. three-phase, 110 000 volts, 60 cycles, and 3 000 k.v.a. three-phase, 110 000 volts, 25 cycles, the maximum sizes being limited only by transportation and installation facilities. Larger sizes are dried by the vacuum process at the point of installation.

Twelve or fifteen years ago 30 000 volt transformers were looked upon with lack of confidence as it was considered that the difficulties in insulating transformers for service at such high voltages increased about as the square of the voltage. With the limited experience available at that time in insulation, design and construction the above statement was probably justified. However, great progress has been made since that time. Now 110 000 volt transformers are common and reliable. In fact these very transformers built for these high voltages seem to be as reliable, if not more so, than transformers wound for lower voltages. This is due to the following reasons:—Transformer insulation is subject to three different strains; those due to the normal working pressure; those due to disturbances set up in the system by switching, grounds and short-circuits, and those due to lightning. The normal working pressure strain is constant; the static strains due to disturbances in the system are more or less frequent, depending upon local conditions; the strains caused by lightning are less frequent, and do not exist in cases of underground transmission systems or localities in which lightning storms are unknown.

Before the advent of the oscillograph little was known as regards the extent of the abnormal static strains set up by disturbances in the system, and it was the practice to insulate transformers for the normal voltage strains. Oscillograms show that these static strains may exceed the normal voltage many times. The reason that more of the earlier transformers did not give trouble was due to the fact that many of them were connected to small systems which were little affected by switching and lightning disturbances. The reason some of them gave so much trouble on certain systems may have been due to the reverse conditions.

Transformers are now being designed more with the intermittent abnormal static strains in mind than the much lower working voltage strain. Also, a transformer for service upon a 110 000 volt system would obviously contain so much insulation that the strains due to lightning and to the switching, etc., on the system might have little or no effect. If the transformer, however, were designed for service upon a 30 000 volt system, its insulation would represent less margin over the strains due to switching, etc. It will therefore be appreciated why these very high voltage transformers have proven so reliable.

TYPES OF THREE-PHASE TRANSFORMER CONSTRUCTION

There are a number of possible forms of three-phase transformer construction, but only three are commonly employed. These are designated as:—"hexagonal type" "core type" and "shell type". In all forms three-phase transformers have their electrical circuits separate, but certain portions of their magnetic circuits in common, that is certain portions of the iron core carry the fluxes of two or of all three of the magnetic circuits. This does not increase the density in the core owing to the phase relations of the fluxes, the resultant of which is less than their arithmetical sum. The magnetic fluxes demanded by two e.m.f's. displaced from each other by 120 electrical degrees can be superimposed in either of two ways; one gives a resultant 1.73 times the value of each, while the other gives a resultant exactly equal to one of the fluxes. The latter is the method adopted in three-phase transformers.

Hexagonal Construction—Three-phase transformers may be built up with three sets of coils arranged on three sections, running out 120 degrees apart from the center to the sides of an hexagonal core, giving a symmetrical arrangement of all phases, electrically and magnetically, as shown in Fig. 1. With this form the coils may not all be wound to the same size, the inner end coils being usually smaller so as to fit into the available space more compactly. This construction necessitates punching the iron laminations for the core into five or six different shapes and lengths. With this construction, round containing cases of minimum diameter may be used, but the design is little used in this country because of the greater mechanical advantage obtainable by the core and shell types of construction.

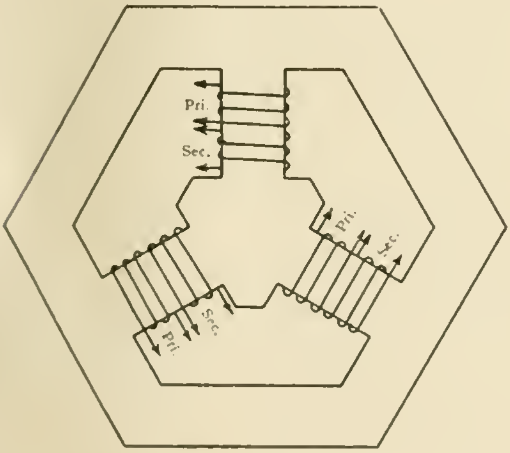
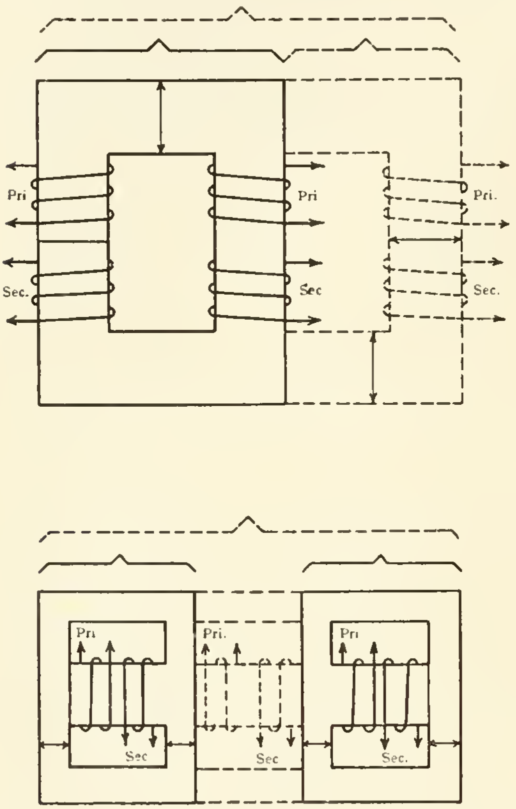


FIG. 1

Core Type—Referring to the single-phase core type transformer illustrated by Fig. 2, it may be seen that by increasing the amount of copper by exactly 50 percent and the amount of iron slightly more than 50 percent, a three-phase transformer is obtained having 50 percent greater capacity than the original single-phase transformer. This is comparing a single-phase transformer with a three-phase transformer of only fifty percent greater capacity and does not include a comparison of cases, oil, etc. A three-phase transformer, equivalent in capacity to three of the single-phase transformers, will be somewhat lighter and more efficient per kilowatt, on account of its increased size. Thus, one line of three-phase transformers of this type is said to weigh 16.5 percent less than three single-phase transformers, each of one-third the capacity, and its losses are also 16.5 percent less. For units of small size the core type is well adapted.



FIGS. 2 AND 3—OUTLINES OF CORE TYPE AND SHELL TYPE TRANSFORMERS

Dotted lines indicate the necessary addition of coils and iron in order to convert single-phase transformers (indicated by full lines) into three-phase transformers, for both the core and shell type of construction.

Butt Joint Construction—This type of construction is a modified form of the common core type. It differs from it in that the laminations of the yokes and the cores are not interlaced as they are in the common core type. Each of the three upright cores and each of the two horizontal yokes is built separately with laminations which are bolted together. This type of construction is seldom used, as it is not ordinarily considered as satisfactory as the normal core type of construction. Its only advantage lies in the fact that it is unnecessary to tear down the laminated iron in order to make repairs, which are sometimes facilitated on this account. Unless carefully constructed, however, there is a tendency for eddy currents to circulate in the region of the butt joints.

Shell Type—Reference to Fig. 3 indicates that by increasing the amount of copper of a single-phase shell type transformer exactly 200 percent, and of the iron approximately 150 percent, a three-phase shell type transformer is obtained, having three times the capacity of the single-phase transformer. By laying out a line of three-phase transformers using the iron of a superseded line of 2 200 volt distributing single-phase shell type transformers, it was found that the total amount of laminated iron for the three-phase transformer cores ranged from 226 to 245 percent with an average of 236 percent of that required in each of the single-phase transformers having one-third the capacity, the amount of copper being of course 300 percent. It will be seen that the three k.v.a., three-phase transformer, Fig. 3 is composed of two one k.v.a. single-phase transformers, and part of a third minus the two iron sides. The reduction in section of iron between the coils is made possible by reason of the fact that the windings of the different phases are so connected that the fluxes in that portion of the magnetic circuit common to two phases 120 degrees apart give a resultant equal to one of them.

THREE-PHASE WINDINGS

Either star or delta connections may be employed with both types of transformers, and the relative advantage of each kind of windings is the same for both single and three-phase transformers. The delta connection is an advantage in some cases in that, if the windings of one phase become damaged by short-circuit, grounding, etc., it is possible to operate the other two windings on open delta. Although a star wound three-phase transformer, with neutral grounded, may be operated on a grounded transmission system on two phases, such installations are so rare that they need not be considered.

DERANGEMENT OF SERVICE IN CASE OF BREAKDOWN

Shell Type—Either three single-phase, delta-delta transformers or one three-phase, delta-delta connected transformer may be operated temporarily at 58 percent of the combined capacity of the three windings provided only one phase has been disabled. In such a case the defective single-phase unit is cut out of service or the defective windings of the three-phase unit, Fig. 4, both high and low tension, are short-circuited. The windings thus short-circuited will choke down the flux passing through the portion of the core surrounded by them without producing in any portion of the windings a current greater than a small fraction of the current which would normally exist in such portion at full load.

If desired, in order to reduce the time of shut down, the twelve transformer leads may be carried to switches mounted near the transformers and connections so made that two of these switches may be closed so as to short-circuit the windings of the damaged phase. This arrangement, however, would necessitate bringing out twelve leads in place of six from the three-phase transformer. A better plan, in case of three-phase shell type, delta-delta connected transformers, would be to furnish them with suitable terminals inside of the case to which could readily be attached pieces of short-circuiting cable furnished at both ends with terminals to fit into those on the transformer terminal board. The connections could then be made inside of the case and extra bushings through the case avoided. In case of star-connected shell type transformers either single or three-phase, a breakdown in one phase will disable the entire service unless the transformers are operated with grounded neutral on a grounded neutral transmission system. In such a case both single and three-phase star-connected transformers may be operated at 58 percent of their original capacity by short-circuiting the damaged windings, both primary and secondary. Lights may then be operated from either of the two live phases to neutral in the normal manner. Satisfactory three-phase motor operation at normal voltage cannot be obtained with this connection, on account of the unbalancing of phases, and reduced voltage. Balanced phases at fifty-eight percent normal voltage, equivalent to a star to delta transformation, may be secured by reversing the polarity of one transformer, by interchanging the leads on either primary or secondary.

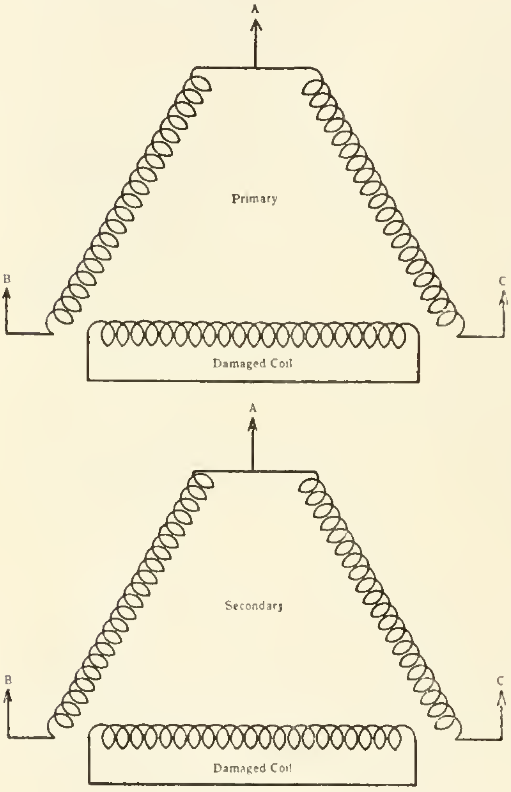


FIG. 4—ARRANGEMENT FOR OPERATING WITH DAMAGED COIL CUTOUT

Core Type—Three-phase core type transformers cannot be operated three-phase with a short-circuit on any phase. The reason may be seen from an examination of the magnetic circuits, in Fig. 3. Sufficient current will be generated in a short-circuited coil to force the flux into some other path than that surrounded by the coil. In the shell type transformer the flux can always be shunted into an iron path, and hence only a small current is generated in the short-circuited coil; whereas in the core type transformer the flux must be forced into a path through the air, requiring a very large current. Of course if the short-circuited coils could be open circuited at the point of breakdown and disconnected from the circuit, the transformer could be operated at two-thirds capacity. A three-phase core type transformer can be built which will not be entirely disabled when one phase is short-circuited, by combining three single-phase core type units one above the other. The difficult mechanical construction and difficulty in cooling such a transformer, however, would make such a type impractical.

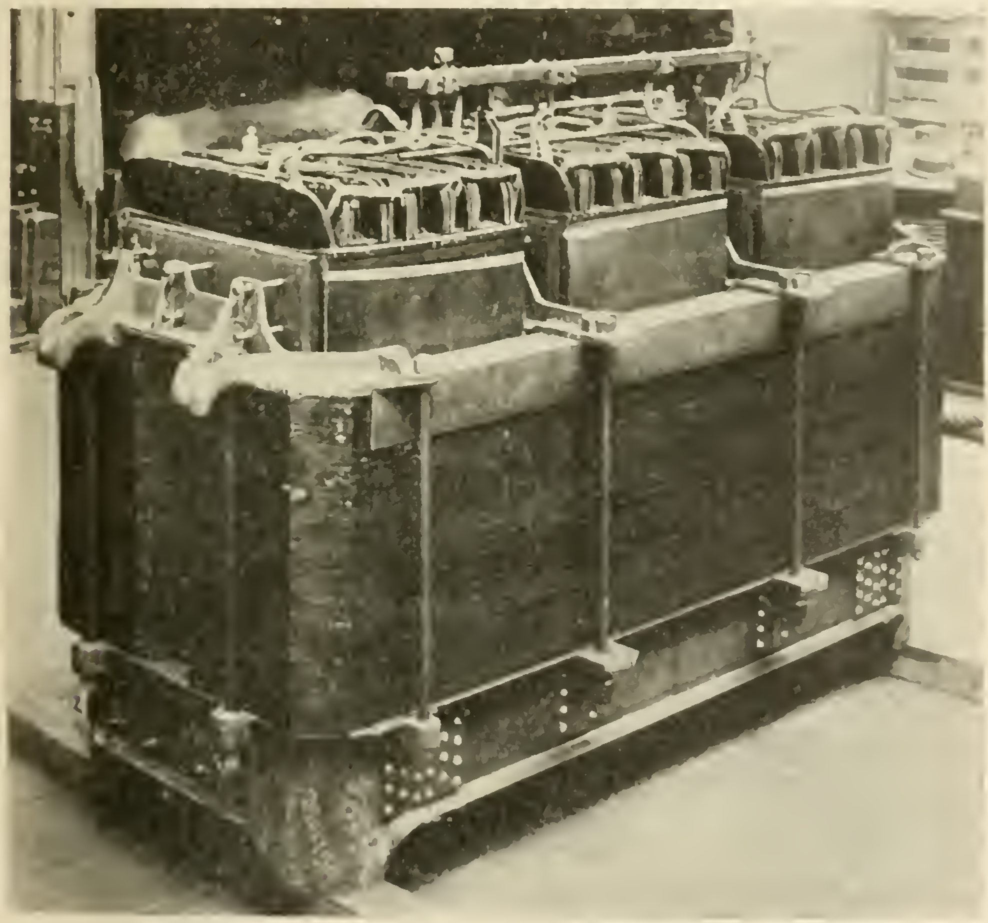


FIG. 5—7 500 K.V.A., THREE-PHASE, 25-CYCLE, 60 000-VOLT SHELL TYPE TRANSFORMER

COST

A three-phase transformer should usually be cheaper to build than three single-phase transformers of the same total capacity. This is due in part to the saving in active core material between adjacent phases on account of the magnetic phase relations. It may be seen, from Figs. 2 and 3 that there is a reduction of about 15 percent in active magnetic iron. Other savings are the use of one large case. (requiring less radiating surface than three small cases on account of higher three-phase efficiency) in place of three small ones; one set of end frames in place of three; one cooling system (in forced cooling types) in place of three, six terminals in place of twelve, and less oil. There is also less material to be handled and it is usually less expensive to build one large unit than several small ones of the same total capacity.

Since three-phase transformers are not so standard in the United States or manufactured in such large quantities, as the single-phase type, it sometimes happens that the expense of developing new or special designs may, in some cases, cause the price to be as high, or even higher than that for three single-phase transformers. This is very likely to be the case on sizes of 10 000 k.v.a. and above, both on account of the new patterns, etc., required and the extra expense in handling such large parts. Neglecting development expense, the first cost of small three-phase delta-delta connected transformers should be, in general, five to ten percent

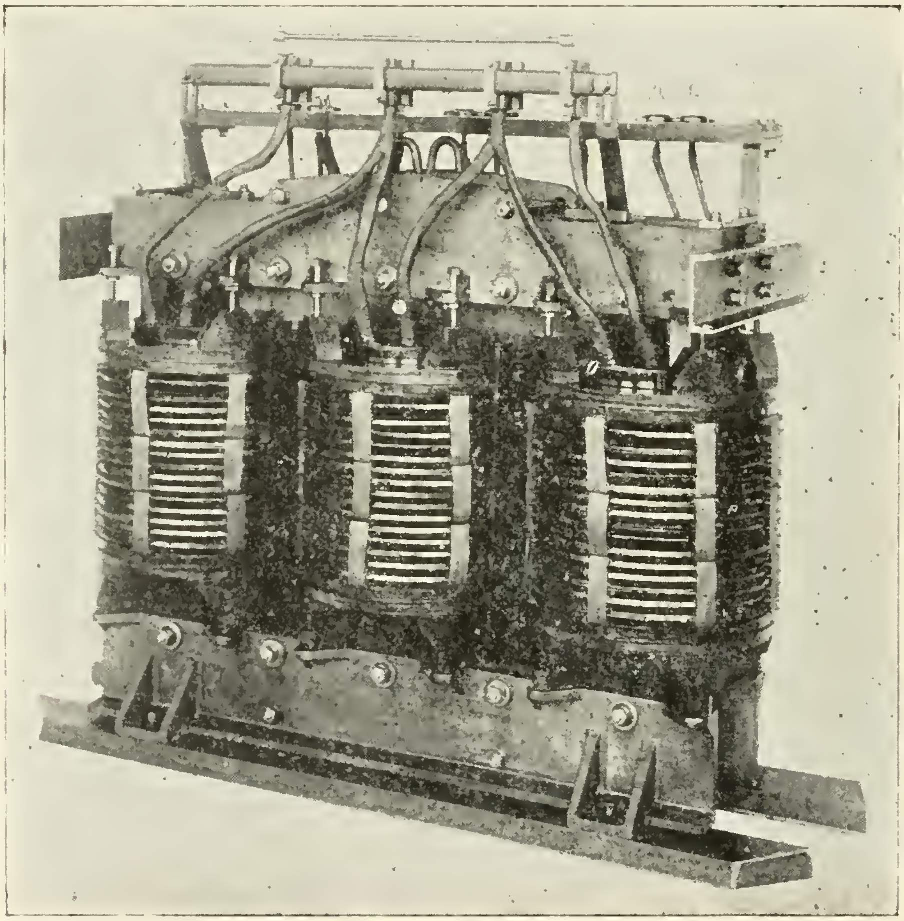


FIG. 6—440 KILOWATT, THREE-PHASE, 22 000-VOLT CORE TYPE TRANSFORMER

less than that of three single-phase units having the same aggregate capacity. In operating three-phase transformers, it is often more desirable in case of breakdown to replace a defective transformer with a complete spare unit, and not to use the three-phase disabled unit temporarily by short-circuiting the windings of the defective delta-connected transformer. In such cases the advantage of delta windings in three-phase transformers disappear and the three-phase transformer may be wound for star connection on the high tension and delta on the low tension side. If a very high voltage is employed the star connection should result in slightly less cost for the three-phase transformer, over the cost of three delta-delta transformers, on account of lower coil voltage.

In general, the cost of three-phase air blast transformers (neglecting the item of development) approximates the cost of equivalent single-phase air blast units at about 3 000 k.v.a.; while for the oil insulated water cooled type, the costs are equal at about 7 500 k.v.a. For sizes larger than these, three-phase transformers usually cost as much or more than three single-phase units. If operators in general would specify three-phase transformers and insist upon having them, the manufacturing cost would soon be lowered due to the increased production, but as long as they are used only infrequently the expense will probably be as high as for three single units.

GREATER COST OF SPARE UNITS

A three-phase spare unit, having three times the capacity of a single unit of one-third the capacity will obviously cost considerably more. In case there is only one three-phase unit of a given capacity and characteristics on a system, this may be of some importance. Usually there are several similar units installed or contemplated in which case the increased price of the three-phase spare may be even less than the saving in first cost of three-phase over single-phase transformers. It should be kept in mind that the continued future growth of the system will be favorable to the three-phase type and that now is the time to standardize on the type most suited for the ultimate future conditions.

EFFICIENCY

Since there is less active material in the three-phase transformer, the losses (at the same densities) will be less, and therefore the efficiencies should be higher. In some cases, however, three-phase transformers may be designed of such relative proportions or of such magnetic densities, as to produce even a lower efficiency than for single-phase units. It is obvious, however, that a comparison of such designs would not be consistent.

Shell Type—The comparative efficiencies given in Table I, are not based on the latest designs but the relative values are correct for this line of distributing type transformers. An inspection of Fig. 3 will show that a three-phase shell type transformer requires just three times as much copper and approximately 2.36 times as much iron as a single-phase transformer having one-third the capacity. Consequently the copper loss would be three times and iron loss 2.36 times as great. The three-phase efficiencies should therefore be slightly higher than those of three single-phase transformers.

TABLE I—EFFICIENCY VALUES FOR A STANDARD LINE OF DISTRIBUTING TYPE TRANSFORMERS AT FULL LOAD

Three Single-Phase Transformers		One Three-Phase Transformer		Increase in Eff. Percent.
Size k.v.a.	Eff. Percent.	Size k.v.a.	Eff. Percent.	
3	95.69	9	96.06	0.37
5	96.41	15	96.72	0.31
7.5	96.71	22.5	97.03	0.32
10	96.90	30	97.17	0.27
15	97.09	45	97.32	0.23
20	97.49	60	97.70	0.21
25	97.61	75	97.80	0.19
30	97.65	90	97.83	0.18
37.5	97.76	112.5	97.93	0.17
50	97.88	150	98.01	0.13

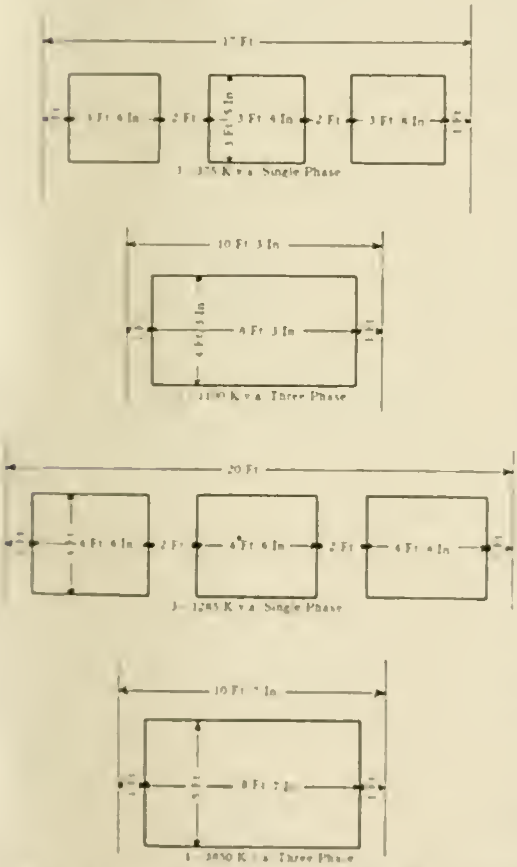
Of course the relative dimensions of the coil openings affect the relative efficiency values, but the principal reason for the smaller increase in three-phase efficiencies in the larger capacities is due to the fact that in the smaller capacities the single-phase line transformers were designed for relatively higher iron loss, whereas in the larger sizes the iron loss was only slightly higher than the full load copper loss. This has been done so as to reduce the constant iron losses in the larger transformers for the purpose of increasing their all day efficiency. The all day efficiency was apparently not considered so important in the smaller capacities.

REDUCED CAPACITY OBTAINABLE IN SELF-COOLING UNITS

In some cases it is highly desirable to use only self-cooling transformers. At the present time the capacity of the largest three-phase self-cooled transformers is approximately 2 000 k.v.a., 60 cycles, at 110 000 volts, or 1 500 k.v.a., 25 cycles at 110 000 volts. These capacities could be increased for lower voltages. A group of three single-phase self-cooling units can be built with an output of nearly three times this amount. Hence if very large outputs of the self-cooling, three-phase type are desired, it might be necessary to install two or three smaller three-phase units, a more expensive arrangement than three-single-phase transformers.

FLOOR SPACE REQUIREMENTS

The actual floor space covered by a three-phase transformer will always be less than for three single-phase units, and on account of the necessity of leaving ventilating spaces and passage ways between single-phase units, the total floor area required for single-phase groups is very much more than that required for three-phase. Figs. 7 and 8 show the floor space required for the two types of transformers of the air blast type construction. The economy of floor space for the three-phase transformers may be of great advantage in cities where real estate is expensive. Usually one bank of transformers is placed directly opposite the rotary converter or motor-generator set it feeds, and often the dimensions of the apparatus fed by the transformers is such as to provide ample space for the bank of single-phase transformers. However, high speed rotary converters and motor-generator sets, due largely to the employment of commutating poles, require very much less floor space than did the older types of these machines. As the speeds increase, the available transformer space should proportionately decrease and the lesser space requirement of three-phase transformers becomes more important. In the case



FIGS. 7 AND 8—OUTLINES SHOWING RELATIVE FLOOR SPACE OCCUPIED BY AIR-BLAST TYPES OF TRANSFORMERS

of vertical rotary converters, the floor space becomes a minimum, a point especially favorable to three-phase transformers. Of course, there are some cases where space limitations will not permit of the use of a three-phase transformer but where three small single-phase units can easily be installed, although possibly not in a symmetrical arrangement. In case transformers are placed in a building or cells by themselves the total cost of the building may be materially reduced by the use of three-phase transformers.

WEIGHT

The weights of three-phase transformers should be less than those of the single-phase type, except in the excessively large capacities when the weights would be greater on account of the very strong and heavy mechanical design necessary to support the heavy three-phase transformers.

REDUCED TRANSPORTATION

The lighter total weight and less space required for three-phase transformers will, in general, result in reduced transportation charges. This advantage may, however, be neutralized in the case of long hauls over mountain roads or poor facilities for handling heavy pieces. In this case the smaller weight and bulk of single-phase units may even become a necessity. Special cars having dropped down bodies are frequently employed for shipping the larger transformers.

TERMINALS

Wherever a high voltage lead passes through the transformer tank or case there is a weak spot. In three single-phase units six high tension leads must be carried through the case (unless the transformers are star connected with neutral grounded to the cores, in which case only one high tension lead would be carried through each case. This latter method, however, is very seldom used. In three-phase transformers, there are only half as many terminals and consequently only about half the chance of terminal trouble.

REDUCED COST OF INSTALLATION

In general it is much cheaper to install one unit than three small ones; particularly in case it is necessary to dry out the transformers at destination by the vacuum process. Less cable and connections are also required for the three-phase units.

INSULATION FAILURES

In the cases where the high tension cables, to which the transformers are connected, are underground or in sections of the country not subject to severe electric storms, the liability to breakdown should be less and the necessity of spare units less urgent.

Shell Type—In this type there is no more liability of insulation breakdown in three-phase transformers than there is in three single-phase units, in fact, the arrangement of coils and iron is the same in both types. The large body of iron between the phases protects the copper in adjacent phases except that portion which projects beyond the cores and here the phases are effectively isolated by fire proof barriers.

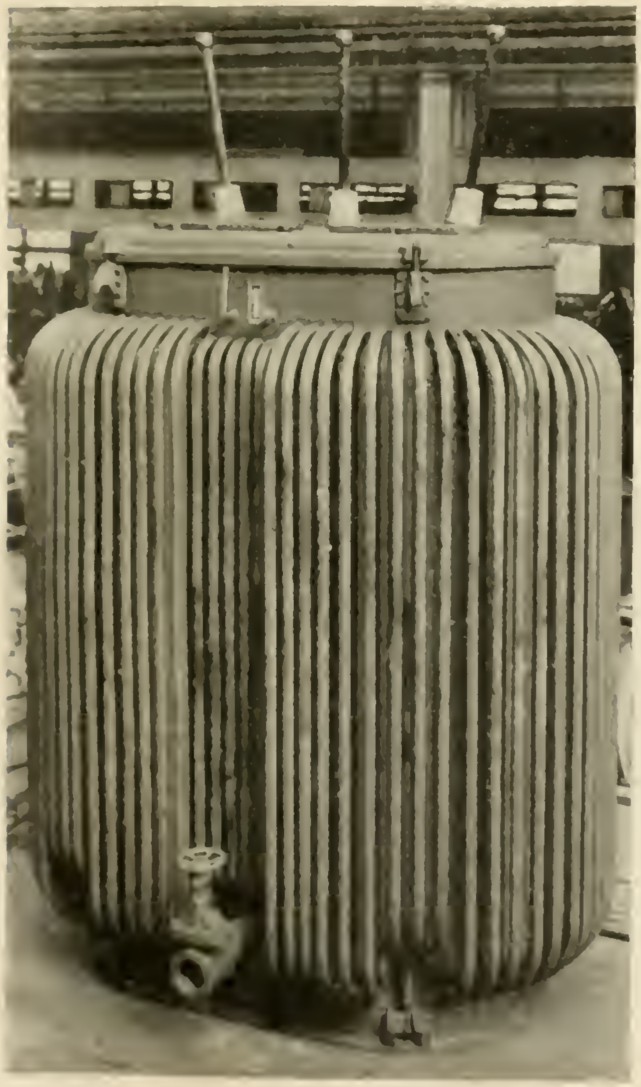


FIG. 9—1 000 K.V.A., 60-CYCLE, 46 000-VOLT OIL INSULATED, SELF-COOLED, THREE-PHASE TRANSFORMER

Core Type—In the core type there is greater liability of a burnout in one phase being communicated to an adjoining phase than in the shell type since the phases are closer together. The long thin coils required by very large core type transformers are of such proportions as to make it very difficult to brace them securely. The result is that, when placed upon circuits subject to severe grounds and short-circuits, there is greater liability to develop insulation breakdowns due to the severe mechanical strains with consequent movement of the coils at the time of severe short-circuits or grounds. For these reasons the shell type construction is usually employed for large capacities.

TAP VOLTAGES

For fairly low voltage transformers, there would be no difficulty in arranging for a number of tap voltages in three-phase transformers, but for extremely high voltages this may become objectionable on account of the limited space in a three-phase unit. In the air blast type this would become still more serious on account of the greater spacing required when terminals are not placed under oil. Tap terminals are sometimes a source of trouble and the present tendency is away from furnishing many of these taps, so that this point seldom needs to be considered.

REPAIRS

In the case of three single-phase transformers, it is probable that, in event of breakdown in one transformer, it would be cut out before the other transformers in the group are damaged. With a three-phase unit where the phases are so near together there is a possibility that a breakdown in one phase may damage one or more of the others. In such event there are two or three phases in place of one to be repaired. However, with oil insulated transformers, circuit breaker protection and barriers between adjacent phases, there should be little likelihood of trouble being communicated to adjacent phases.

In general the repair of a three-phase transformer will be more difficult than for a single-phase type of similar construction. This is particularly true in extremely large capacities on account of the difficulty of handling the large parts.

OUTSIDE WIRING

In three-phase transformers, the star and delta connections are easily made inside the case, requiring no outside cross-connections. In the case of single-phase transformers these connections must of course be made outside of the case.

Transformers for Manhole Service—Manholes are usually cramped for space and the seat of a great deal of transformer trouble. Such trouble is frequently caused by poor leaded joints between the lead sheath surrounding the cable and the transformer terminal, allowing water to get into the transformer. Three-phase transformers for this service have a certain advantage over three single-phase transformers, in that they require less space and only six soldered joints in place of twelve. A disadvantage of three-phase transformers for this service would appear in the larger sizes which would probably require extra large and special manhole covers. Standard lines of three-phase manhole type transformers are now on the market.

Pole Service—For pole mounting, three-phase transformers present a more pleasing appearance, require less space and total weight than three single-phase transformers. On the other hand the weight of a three-phase unit would be between two and three times that of a single-phase transformer of one-third the capacity. It is customary with some power companies to mount as many as three 25 k.v.a., or larger, single-phase transformers on poles having standard cross-arms. A 75 k.v.a., three-phase transformer to do this work might be difficult to handle and this greater weight in one unit might require some sort of platform to support it.

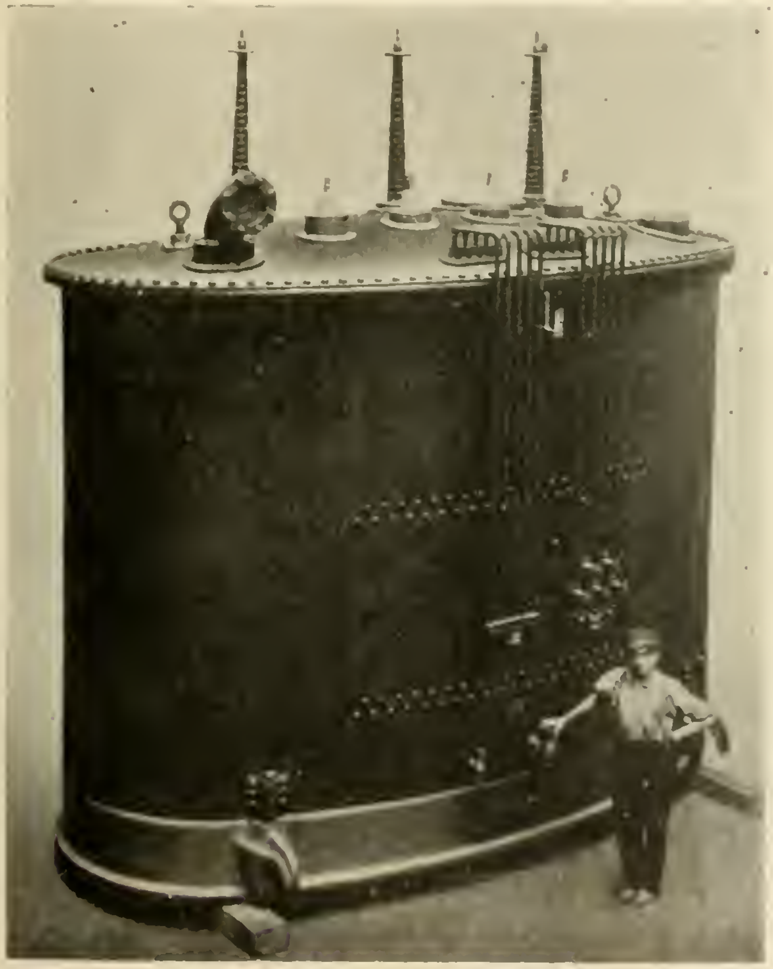


FIG. 10—10 000 K. V. A., 25-CYCLE, 66 000 VOLT OIL INSULATED, WATER COOLED, THREE-PHASE TRANSFORMER

Lighting and Power Service—Most lighting service is furnished at either 110-220 volts, three wire, or 110 volts, two wire.

whereas motor service is usually furnished at 400 volts, three-phase, although some is furnished at 220 volts both two and three-phase. The present tendency is 110-220 volts, three wire, for lighting, and 440 or 550 volts, three-phase for power service. Until recently standard single-phase distributing transformers could be obtained which were wound for all three secondary voltages, 110-220 and 440 volts. As spares of such transformers would answer for both lighting and power service, it was unnecessary to carry two sparate lines of transformers; one line for lighting and another line for power service. Standard distributing transformers are no longer furnished wound for all three voltages, so that it is now necessary to carry transformers for both kinds of service. Since two lines of transformers and spare units are now required the old objection, that three-phase power transformers require an additional line of transformers, largely disappears.

SUMMARY

There are so many minor advantages and disadvantages applying to both types of transformers that a concrete summary is difficult. If the prices and efficiencies commonly quoted were uniformly consistent with the fundamental differences in the two types as regards cost and efficiency, then a definite statement could be made as to when each type should be selected. Even then, however, any one of the above mentioned differences of the two types might become ruling in a specific case.

It may be stated, however, that for feeding motors, rotary converters and motor-generator sets, three-phase transformers will, in the near future, be very generally employed. In fact, at the present time they are being largely selected for this class of service, and it may be expected that they will become as popular in America as they have already become in Europe.

LARGE TURBINE DRIVEN DIRECT-CURRENT GENERATORS

DAVID HALL

THE development of direct-current generators of large output cannot be analyzed without taking into consideration the desirable speeds of their prime movers. The large reciprocating engine inherently operates at a low speed and a number of units of 2700 kilowatts capacity at 75 revolutions per minute have been installed in years past. Such units, however, are very heavy and require much floor space, as well as overhead space. Primarily the speed of 75 r.p.m. was chosen to accomodate steam engine requirements, but it was fairly suited for direct-current generators not provided with special means for securing good commutation.

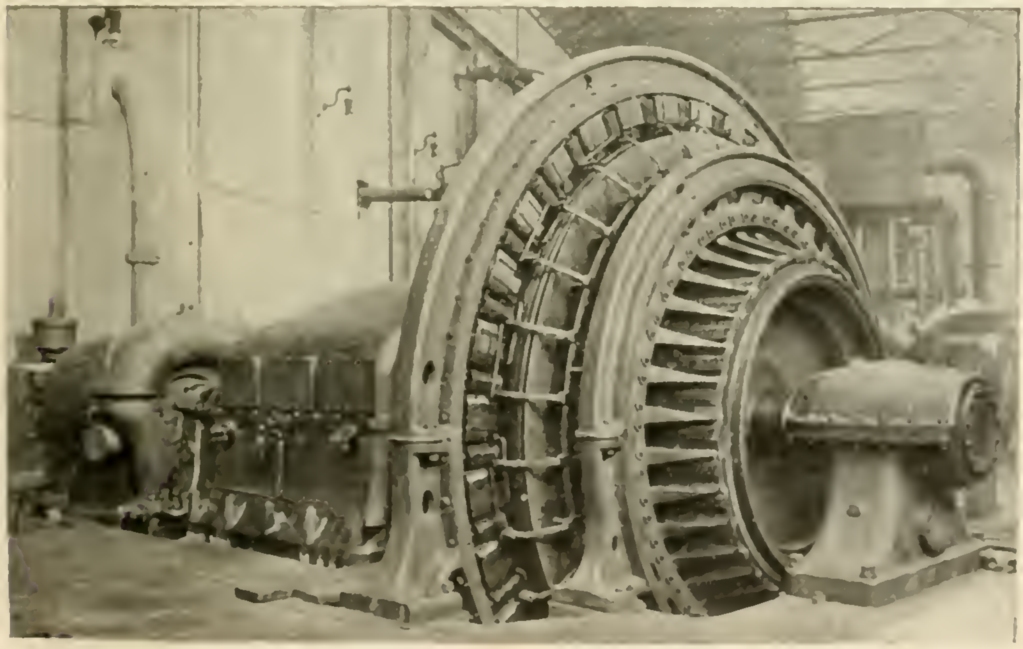


FIG. 1—GENERAL VIEW OF 3750 KILOWATT GEARED DIRECT-CURRENT TURBO-GENERATOR SET

The introduction of a number of special features for assisting commutation, such as commutating poles, together with other improvements, has made possible the building of machines of much larger outputs at much greater speeds; hence the necessity for a prime mover which will operate economically at a relatively high speed as compared with the speed of the steam engine, but of a speed far below the economical speed of the steam turbine.

The introduction of a reduction gear between a steam turbine and the generator permits the turbine to run at the speed of best economy, and gives the generator a satisfactory speed for economical design and good operation. This combination results in a unit requiring much less floor space than would be occupied by a reciprocating steam engine unit of equivalent capacity. Floor space is not, however, the chief feature of importance as the combination has made possible an increase in the maximum possible capacity per unit. The recent installation of two units, each having a maximum rated continuous capacity of 3 750 kilowatts, 275 volts, 13 600 amperes, 180 r.p.m., at the Canal Street power house of the Cleveland Electric Illuminating Company, constitutes a new record of output obtainable per single direct-current unit at this voltage. Two views of one of these sets are shown in Figs. 1 and 2. That these sets are of relatively small dimensions can be seen by referring to Fig. 3. The overall length of this unit is 37 ft. 2 in., maximum width 21 ft. 4 in., and 13 ft. 5 in. high above the floor line. The width of 21 ft. 4 in. is the extreme distance as measured across the feet of the generator frame, whereas the width of the turbine and gear is only 14 ft. 6 in., which suggests a further development of a double unit of 7 500 kw capacity which will be referred to later.

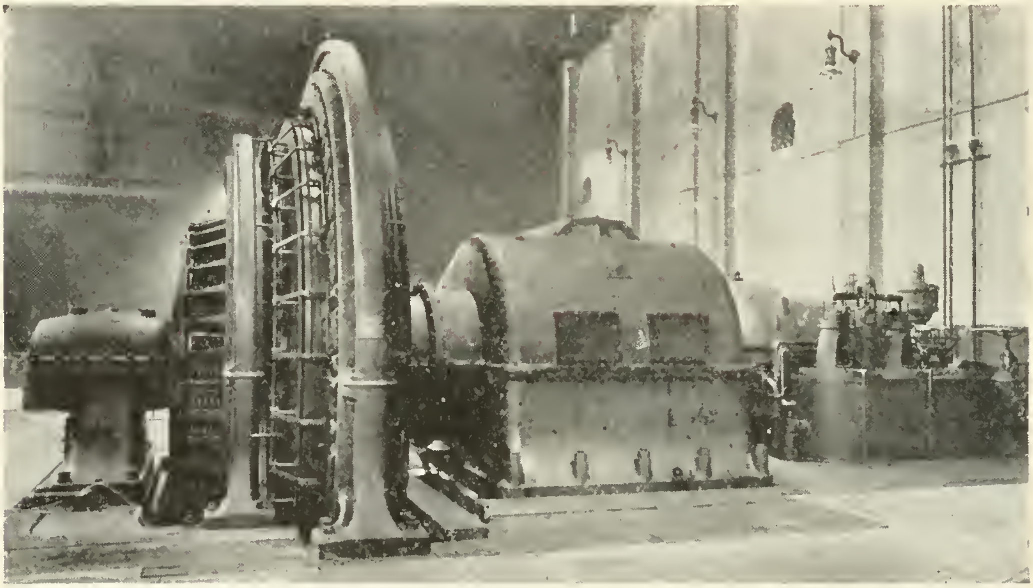


FIG. 2—VIEW OF SET SHOWING SIDE ELEVATION OF GENERATOR AND REDUCTION GEAR.

As compared with reciprocating engine-driven units of much smaller outputs, this unit occupies less space; it is lighter, and it is more accessible. The light weight and ease of assembling may be judged from the fact that the time, from the date of shipment until the unit was ready for operation in Cleveland, was only twenty-three days; and twelve days after it was first started, it carried loads in excess of 4 000 kilowatts.

These steam turbines operate with steam at 165 pounds initial and 15 pounds gauge back pressure and run at a speed of 1 800 r. p. m. The exhaust steam is used for commercial steam heating purposes, as this plant furnishes steam for a portion of the business district of the city. The large gear of the reduction gear* is 100 inches in diameter and, with a ratio of 10 to 1, gives a speed of 180 r.p.m. to the generator. The generators are shunt-wound, commutating-pole machines having 32 main poles. The armature and commutator diameters are respectively 180 and 90 inches, giving surface speeds of 8 500 and 4 250 feet per minute. The magnet frames are made of cast steel properly shaped to give

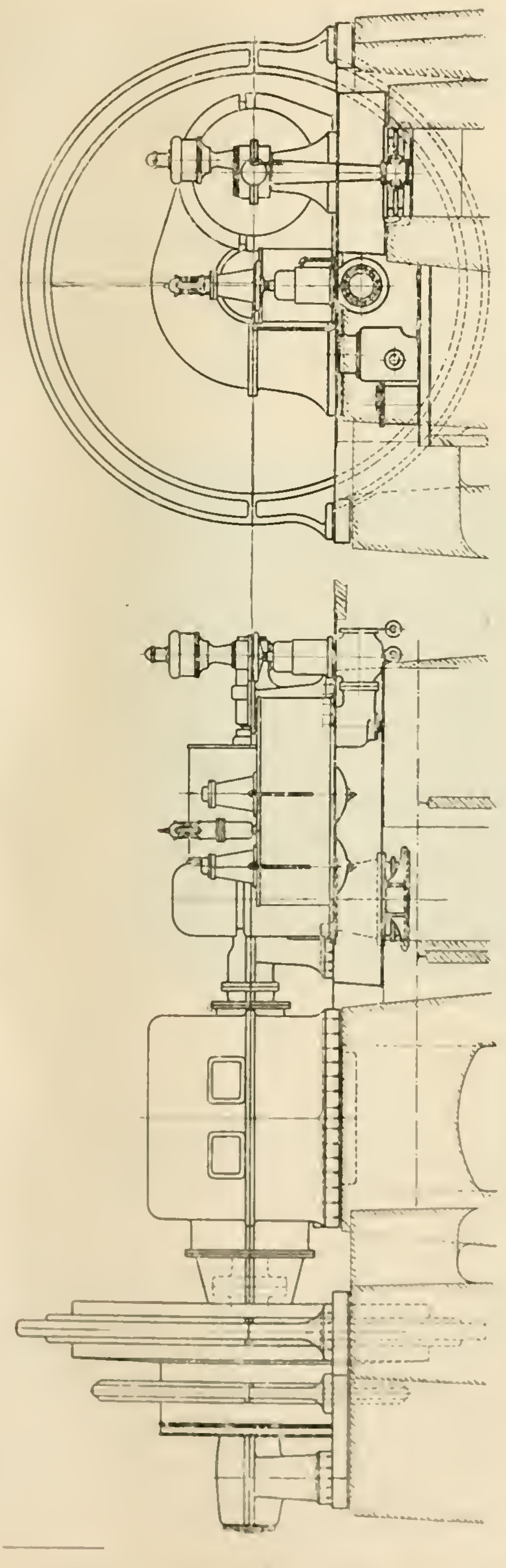


FIG. 3—SIDE AND END ELEVATIONS OF 3 750 KW GEARED DIRECT-CURRENT TURBO-GENERATOR SET
Overall length, 37 ft., 2 in.; width, 21 ft., 4 in.; height above floor, 13 ft., 5 in.

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*See article by Mr. H. E. Longwell in the JOURNAL for Jan., 1912, p. 61.

stiffness. The brush brackets are carried from a cast iron ring, similar in section to the main frame. The complete weight of the unit is 356 000 pounds or less than 100 pounds per kilowatt. The generator complete with shaft weighs 163 000 pounds; the gear, 40 000 pounds.

Further development of the application of this gear can be made by applying a turbine to each side of the main gear, thus driving with two turbines instead of one and thus doubling the capacity of the set. In order to double the generator capacity two machines are used in tandem as shown in Fig. 5. This illustration gives the dimensions of a double unit of 7 500 kilowatt capacity. By comparing the dimensions of this set with a single set it will be seen that the capacity of the set can be increased 100 percent with an increase of only 32 percent in rectangular floor space and the same overhead space.

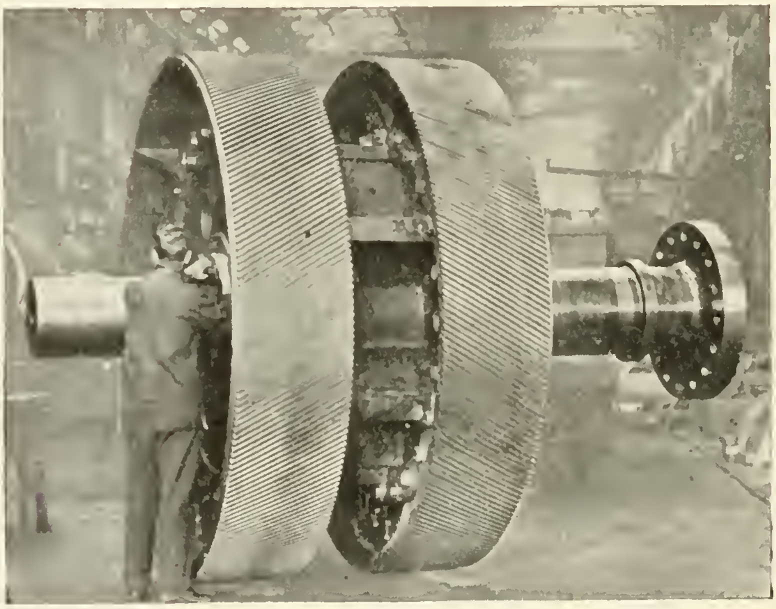

FIG. 4—VIEW OF LARGE REDUCTION GEARS BEFORE BEING ASSEMBLED IN GEAR CASE.

This development eliminates the prime mover as the limiting factor, and makes the generator the determining factor in the maximum output of a direct-current unit. In this connection, the ampere rating of the generator is one of the determining factors. For example, if limits are assumed of 900 amperes per brush arm, eight inches between brush arms and 4 500 feet per minute commutator speed, it follows that for a given ampere rating, the speed for a single commutator machine can be determined from the following formula:—

$$\text{R.p.m.} = 4\,500 \left(\frac{900}{\text{Total amp.} \times 2}\right)^{\frac{12}{8}}$$

These are not all the limiting factors, but they serve to indicate that the maximum rating obtainable, as well as the general features of design, depend upon the voltage. For low voltages and large currents, double commutators are necessary to obtain maximum ratings at maximum speeds. For higher voltages, 600 volts for example, it is possible to build larger capacities, and by making proper provisions for commutation, single commutator machines of 6 000 to 8 000 kilowatts can be built.

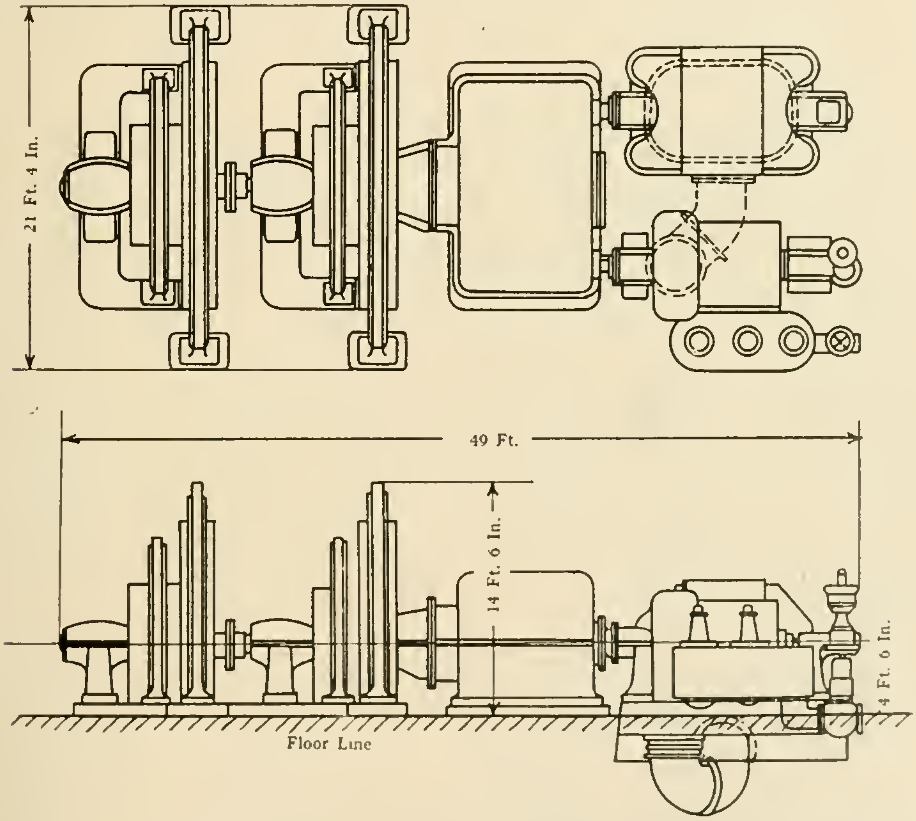

FIG. 5—OUTLINE PLAN AND ELEVATION SHOWING METHOD OF SECURING LARGE CAPACITY BY PLACING A TURBINE AT EACH SIDE OF THE REDUCTION GEAR AND TWO DIRECT-CURRENT GENERATORS IN TANDEM

The apparent discrepancy in vertical height of generator above floor line is due to different elevation of floor lines in Figs. 3 and 5.

MATERIALS USED IN ELECTRICAL HEATERS

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FROM the description of the various types of electrical heaters, given in the last issue, it can readily be understood that the raw materials required have to meet a great many different conditions; in fact quite a number of substances had first to be developed before satisfactory results could be obtained. The most important raw materials entering into the construction of electrical heaters are:—

1—Electrical conductors.
2—Thermal conductors.
3—Electrical and thermal insulators.

ELECTRICAL CONDUCTORS

Electrical conductors are employed for the materials of the resistors, for the electrodes of the electric arc, for the terminals of the electric spark and for the substances in electrolytic processes.

The Resistor Materials are mostly metals or alloys in form of round or flat wire, sheet or film. With the evergrowing and more exacting demands of the heating industry, special high resistance alloys have been developed, which more or less fulfill the requirements of—

High specific resistance.
Low temperature coefficient of resistivity.
Mechanical strength.
Uniform section.
No deterioration or aging, due to the repeated heating and cooling.
No oxidation, even though operated at red heat.
High melting point.

The development of the art is clearly illustrated by Table I, although the information is not entirely complete; in fact the exact composition of many alloys is a trade secret, each alloy simply being known under its "trade name."

The first group of substances in Table I are copper and platinum. Copper, while occasionally used as a conductor in resistors, is included merely in order to compare its properties with those of the "resistance" alloys. Platinum is almost the only substance amongst metals and alloys which can be operated with temperatures as high as 2 650 to 2 850 degrees F. For this reason it is still being used regardless of its high price.

The second group of substances, the copper-nickel-zinc alloys, represented mostly by the mixtures known as "German silver," were the first alloys especially made to satisfy the demand of the electrical industry for a resistance material. While there is still a considerable amount of German silver being used for electrical purposes, this alloy, like all other zinc alloys, gives very little satisfaction in the heating industry, as the repeated heating and cooling makes it brittle.

The third group of substances, the copper-nickel alloys, was a decided improvement over the three metal mixtures, but their specific resistance as well as their maximum working temperature were still entirely too low to fulfill the requirements for heating appliances.

TABLE I—RESISTOR METALS AND ALLOYS

Name of Substance.	Physical Condition or Composition of Substance.	Exclusive Mfr. or Agent.	Resistance in Ohms per circ. mil. foot at 68° F	Temperature Coefficient of resistivity for one degree, F	Specific gravity g. per cu. cm.	Approx. Maximum Working Temperature in degrees, F	Approx. Melting Point in degrees, F
Copper	Annealed	—	10.4	0.00393	8.89	500	1980
Platinum	Pure	—	57.4	0.00204	21.5	2700	3190
German Silver	18%-Copper-Nickel-Zinc	—	200	0.000172	8.5	500	1880
German Silver	30% " " "	—	290	0.000111	8.5		2120
Ia Ia Soft	Copoer-Nickel	1	283	0.0000278	8.4	700	2250
Advance	" "	2	294	nil	8.9	700	2300
Constantin	" "	3	300	0.00000278	8.6		
Ideal	" "	4	300	0.00001	8.85	700	2200
Krupp	Nickel-Steel	5	511	0.00039	8.10	1100	
Superior	" "	1	517	0.00045	8.4	1000	2100
Climax	" "	2	525	0.0004	8.14	1000	2300
Phenix	" "	4	520	0.0003	8.09	1000	2100
Excello	Nickel-Chromium	1	550	0.00009	8.9	2000	3000
Nichrome	" "	2	600	0.00024	8.15	2200	2800
Calido	" "	4	600	0.00019		2000	2800
Nichrome II	" "	2	655	0.00009	8.02	2000	2850
Calorite	" "	6	720			1000	2370
Carbon	Retort	—	4325*	not constant	1.8	6000	6700
Graphite	Acheson	—	4875*	" "	2.2	6000	6700
Carb. Filament	Treated	—	6950**	" "		3500	6700

*At 5400 degrees, F. ** At 3500 degrees, F.

1—Hermann Boker & Co., New York.
2—Driver-Harris Wire Co., Harrison, N. J.
3—C. Schniewindt, Neuenrade, Germany.
4—The Electrical Alloy Co., Morristown, N. J.
5—Thomas Prosser & Son, New York.
6—General Electric Co., Schenectady, N. Y.

The fourth group of substances, the nickel-steel alloys, appeared in the market a little over twenty years ago, with a specific resistance more than fifty times that of copper and with a maximum working temperature of approximately 1 000 degrees F. Nickel-steel alloys have the disadvantage of rusting in the open air.

In the fifth group of substances represented by the nickel-chromium alloys, some of which are mixed with a small amount of iron, this difficulty is overcome. They were put on the market not quite ten years ago and not only withstand rusting fairly well, but also have a very high specific resistance and maximum working temperature. It is safe to state that these alloys answer all ordinary requirements, and that a carefully designed device equipped with nickel-chromium wire will not burn out, one of the principal troubles in the early days of the electrical heating industry.

The last group of substances, "carbon" and "graphite," stands in a class by itself. These materials are used to produce temperatures which metals and alloys, even platinum, will not stand, but as pointed out before, must be worked in a vacuum or must be enveloped in a gas free from oxygen to prevent oxidation. Carbon and graphite are the only substances with a "negative" temperature co-efficient, in consequence of which carbon resistors have not the usual "inrush" of current when put in service.

There are other substances, such as kryptol, silundum and quartz, which can be used for resistors, but as they have not as yet been put into practical use to any extent, they are not included.

For Electric Fuses, the resistor materials just described will not answer, as, contrary to all other electric heaters, in this case, the substance is supposed to melt with a predetermined amount of current passing through. At first, only metals or alloys with a low melting point were used, such as tin, lead and tin-lead alloys, but it soon developed that aluminum and copper are preferable for large capacities, as considerable less volume of metal has to be melted in blowing the fuse, and that platinum is more desirable for very small capacities, such as telephonic and telegraphic circuits, also circuits for firing blasting charges, as it does not oxidize and thereby increases the surety of the interruption of the electric circuit with the predetermined amount. The fusing points of tin-lead alloy, aluminum, copper and platinum are given in Table II. They also show, how, in commercial practice, by adopting for the tin-lead alloy "rated carrying capacities" considerably below the actual fusing point, the uncertainty of the latter is eliminated for all ordinary requirements.

Although Electrodes for the Electric Arc have been used for more than thirty-five years in arc lighting, much difficulty was encountered in producing satisfactory electrodes for electric arc furnaces. The enormous currents require carbons of very large cross-section, as high as 24 inches in diameter and in lengths up to 100 inches, and years passed by before material for such large diameters could be made sufficiently homogeneous. The raw materials employed are graphite, petroleum coke, anthracite coal and anhydrous tar. The solid materials are ground, kneaded with tar and the scarcely plastic mixture is then stamped into big blocks. Finally these are pressed into the desired shape of the electrode and baked in ovens under a covering of ground coal or treated in electric furnaces. In accordance with the various requirements, the electrodes are made round, square, rectangular, in form of tubes, crucibles, bricks, etc. In most cases, the electrodes of a furnace extend from the outside through the heat insulating walls into the chamber and therefore have on the outside a temperature slightly above the one of the surroundings and on the inner end the temperature of the arc, representing a difference of several thousand degrees. At the same time they carry currents of thousands of amperes, which develop considerable heat by the joulean effect. It therefore can readily be understood that the electrodes should have good electrical but poor thermal conductivity and that the proper selection of the most efficient diameter and length of electrodes is a very important factor. As the industry is still in its infancy and the requirements vary considerably for different purposes, standards have not yet been established.

TABLE II—FUSE METALS AND ALLOYS.

Tin-Lead Alloy.					Other Metals.			
Rated Carrying C'p'city in Amp.	Fusing Current in Amp.	Length of Fuse in Ins.	Diam. of Wire in Mils.	Section of Ribbon in Inches.	Fusing Current in Amperes.	Diameter of Wire in Mills. Alum'in.	Copper.	Plat'm.
⅛	½	1	2.5		0.164			1.0
¼	¾	1	4.5		0.300			1.5
½	1½	1	10		0.463			2.0
¾	2¼	1	13		0.647			2.5
1	3	1¼	16		0.850			3.0
2	5	1½	25		1	2.6	2.1	3.3
4	9	1¾	35		2	4.1	3.4	5.3
6	12	2	42		3	5.4	4.4	7.0
8	15	2	49		4	6.5	5.3	8.4
10	17	2¼	55		5	7.6	6.2	9.8
15	24	2¼	68		10	12.0	9.8	15.5
20	30	2½	82		15	15.8	12.9	20.3
25	37	2¾	94		20	19.1	15.6	24.6
30	43	2¾	103		25	22.2	18.1	28.6
40	56	3	122		30	25.0	20.5	32.3
50	69	3	137	0.360x0.047	40	30.3	24.8	39.1
60	81	3¼	158	0.440x0.047	50	35.2	28.8	45.4
80	106	3½	189	0.375x0.078	60	39.7	32.5	51.3
100	129	4	226	0.440x0.094	80	48.1	39.4	62.1
150	187	4½		0.570x0.094	100	55.8	45.7	72.0
200	243	4¾		0.875x0.094	150	73.0	59.8	
250	298	4¾		1.000x0.110	200	88.6	72.5	
300	354	5		1.000x0.150	250	102.8	84.1	
400	470	5¼		1.000x0.200	300	116.1	95.0	
500	550	6		1.250x0.240				
600	675	6½		1.500x0.200				

Terminals or electrodes for the electric spark should neither pit, burn, corrode, warp or become incandescent by the action of the spark. Therefore it is necessary to employ metals or alloys which have a high melting point, do not corrode, are good thermal conductors, and show little tendency to arc. Platinum, iridium, tungsten have been and are being used with success, but by far the most suitable metal is nickel and its alloys, such as meteor metal, nickel-chromium and manganese-nickel.

THERMAL CONDUCTORS

All materials located between the source of the heat and the substance, whose temperature is to be elevated, must be good thermal conductors in order to obtain quick action and to make the loss of heat in the transmission a minimum. A number of substances as indicated in Table III, are used in actual practice for this purpose. Copper and silver are not only the best conductors, but they also require very little energy for increasing their own temperature. On the other hand, water and air are the poorest conductors and absorb considerable energy for raising their temperature. Table III is so arranged that column *3* expresses the conductivity and column *5* the specific heat in the number of watts required per second for the English units of measure, eliminating the necessity of transposing a number of figures from the English system into the c. g. s. system and vice versa.

TABLE III—THERMAL CONDUCTORS

Name of Substance.	Thermal Conductivity.		Specific Heat.		
	Conductiv. * in g-cal. per sec. per deg. cent.	Watt-sec. * per cu. in. per degree Fahrenheit.	Specific Heat Water—1.		**Watt-sec. per Ounce per degree Fahrenheit.**
Silver	1.0960	6.4644	0.0559	**	3.686
Copper	0.7189	4.2415	0.08988	*	5.923
Aluminum	0.3435	2.0267	0.2022	*	13.600
Zinc	0.3030	1.7877	0.0935	**	6.150
Yellow Brass	0.2041	1.2042	0.093	*	6.125
Iron	0.1665	0.9824	0.1249	***	8.225
Soft Steel	0.1110	0.6549	0.108	*	7.110
Graphite, solid	0.0250	0.1475	0.30	***	19.78
Carbon, solid	0.0148	0.0873	0.2–0.3	*	13.18–19.78
Water	0.0012	0.0071	1.0	*	65.93
Air, const. pressure	0.0006	0.0034	0.2374	*	15.62

*At about 0 degrees, C. **At 0-100 degrees, C. ***At 200 degrees, C.

It can be assumed that the conduction of heat is governed by the same rule as the transmission of electrical energy, as expressed by Ohm's law, except that the former does not act instantaneously and is therefore subject to a time element. Under these conditions it can easily be understood that the section of the heat conducting material should be made as large as possible and the thickness reduced as far as mechanical strength will permit, unless the mass of material is increased for the purpose of using it as a "heat reservoir" like the cast iron bottoms of sad irons.

TABLE IV—PROPERTIES AND APPLICATION OF ELECTRICAL INSULATORS

Name of Substance	Manufacturer	Max. Working Temp. in Deg. F.	Min. Thickness Used —Inch	Dielectric Strength in Volts Per Mil.	Application and Properties of Substance
Enamel Film		400	0.0015	550-600	Applied for coating bare electrical conductors. Moisture proof, hard, tough, elastic, should not come in contact with alcohol, shellac, turpentine, vegetable oils, etc., insoluble in mineral oil.
Bakelite-Asbestos		450	$\frac{1}{8}$	200	Applied in moulded form. Moisture proof, hard, strong, not affected by acids, oils, alkalis, does not warp.
Asbestos-Paper		500	$\frac{1}{64}$	100	Applied in sheets for covering metal bodies. Soft, flexible, little mechanical strength, absorbs moisture easily and therefore can only be used in dry places. The commercial product often contains iron and other imprities, reducing the dielectric strength to almost nothing.
Asbestos-Tape (Deltatape)	1	500	0.010	250	Applied for covering bare electrical conductors. Soft, flexible, strong, moisture proof.
Vulcabeston	2	500	$\frac{1}{64}$	130	Applied in sheet and moulded form. Hard, strong, not affected by acids, oils, alkalis, does not warp, softens above 500 deg. F., but does not carbonize, can be highly finished.
Sternoid	3	600	$\frac{1}{8}$		Applied in moulded form. Hard, strong, moisture proof, non-combustible, can be highly finished.
Condensite	5	600	$\frac{1}{8}$	135	Applied in moulded form. Hard, strong, insoluble in oils, moisture proof, finished in black.
Gummon	4	700	$\frac{3}{16}$	75	Applied in moulded form. Hard, but not very strong, moisture proof, can be highly finished.
Natural Mica		700	0.005	400-700	Applied in sheet form. Moisture proof, hard, strong, insoluble in oils and most acids, does not warp or shrink, non-combustible.
Built-up Mica		1000	0.005	400-600	Applied in sheet and moulded form. Only built up mica made with a binder which will not disturb the insulating qualities of the mica, when heated up, can be used. The binder in the products known as mica plate, micanite, flexible mica, megomit, megotalc ordinarily does not fulfill these requirements. Flexible, strong, does not warp or shrink, according to binder absorbs moisture or is non-absorptive.
Mica-Paper		1000	0.001	200-300	Applied in form of tape for covering bare electrical conductors. After the conductor is wrapped, the paper must be burned off, leaving the pure mica as insulator. Means have to be provided to hold the mica in place. Excellent method to insulate lead wires, when space is limited.
Asbestos-Fibre		1000	0.035	100-180	Applied in form of woven cloth and fibre for covering flexible, portable heaters and bare electrical conductors. Soft, flexible, strong, absorbs moisture easily and therefore can only be used in dry places, melts with about [illegible] deg. F. The commercial product often contains iron and other impurities, reducing the dielectric strength to almost nothing.

1. D. & W. Fuse Co., Providence, R. I. 2. Johns-Manville Co., New York, N. Y. 3. Dickinson Mfg. Co., Springfield, Mass. 4. Hemming Mfg. Co., Garfield, N. J. 5. Condensite Co. of America, Glenridge, N. J.

TABLE IV—PROPERTIES AND APPLICATION OF ELECTRICAL INSULATORS—Con.

Name of	Manufacturer	Max. Working Temp. in Deg. F.	Min. Thickness Used —Inch	Dielectric strength in Volts Per Mil.	Application and Properties of Substance
Glazed Porcelain		1500	$\frac{1}{8}$	200-800	Applied in moulded form. Hard, strong, not affected by acids, oils, alkalis, moisture proof, can be highly finished. Becomes a fair conductor at high temperatures, so that it cannot be used for furnace work, although it requires about 2 750 deg. F. to fuse it.
Electrobestos	2	1800	$\frac{1}{8}$	50	Applied in moulded form. Hard, but not very strong, not affected by acids, oils or alkalis, but absorbs moisture.
Hemit B	4	2000	$\frac{1}{8}$	30	Applied in sheet or moulded form, the latter only, if the shapes are not complicated. Hard, but not very strong, not affected by acids, oils or alkalis, but absorbs moisture. Can be machined, drilled, sawed and polished.
Soapstone		2000	$\frac{3}{16}$		Applied in slabs. Soft, not very strong, not affected by acids, oils or alkalis, can be machined, drilled and sawed, absorbs moisture.
Lava	6	2000	$\frac{1}{16}$	75-250	Can be machined as accurately as brass in natural state and before being baked. Hard, moisture proof, not affected by acids, oils or alkalis.
Fire-Clay		2000	$\frac{1}{8}$		Applied in semi-liquid form and baked, after the bare electrical conductors are embedded. Becomes a fair conductor at high temperatures. Not affected by acids, oils, alkalis.
Alundum		2000	$\frac{1}{8}$		Applied in moulded form for supporting bare electrical conductors.

2. Johns-Manville Co., New York, N. Y. 4. Hemming Mfg. Co., Garwood, N. J. 6. American Lava Co., Chattanooga, Tenn.

ELECTRICAL AND THERMAL INSULATORS

While there is a considerable amount of data in existence on electrical and thermal conductors, very little reliable information is on record regarding electrical and thermal insulators, due to the fact, that the properties of the insulating materials vary considerably with the working conditions. In general, it may be stated that good electrical insulators are also good thermal insulators. As the design of a great many heaters demands an electrical insulator between the source of the heat and the thermal conductor, which transmits the heat, it can readily be seen that the electrical insulators often should be good thermal conductors. Since such substances are not known, the next best method which can be pursued is to employ thermal insulators with the least possible thickness, so that they offer a minimum of resistance to the transmission of heat. With this point in view, an attempt is made in Table IV to enumerate a number of insulating materials in accordance with the maximum working temperature and the minimum thickness at which they can be used in actual practice.

In other places, except between the source of heat and the thermal conductor, which transmits the heat, the electrical insulating materials have to be thermal insulators as well, and providing the space is not limited, it is therefore desirable to employ a maximum thickness. In order to give an idea of the losses, sustained through thermal insulators, the table below gives approximate figures of the loss of heat expressed in watts per second for one cubic inch of the various substances with a temperature difference of one degree F. between opposite sides.

TABLE V—THERMAL INSULATORS

Name of Substance	Therm. Cond. in Watts per Sec. per Cu. In. for One Deg. F.	Name of Substance	Therm. Cond. in Watts per Sec. per Cu. In. for One Deg. F.
Cotton-pressed	0.00019	Oak	0.00354
Cotton-wool	0.00025	Cork	0.00423
Lava	0.00047	Sand	0.00594
Felt	0.00051	Water	0.00708
Fir, across grain...	0.00053	Plaster of Paris....	0.00766
Sawdust	0.00071	Glass	0.00885
Wood Ashes	0.00100	Cement	0.00960
Fir, along grain....	0.00177	White Marble	0.0100
Inusional earth	0.00224	Asbestos Mill board.	0.0179
Paper	0.00236	Slate across cleavage.	0.0212
Carbon	0.00239	Fire brick	0.0248
Magnesia	0.00272	Slate along cleavage..	0.0383
Pine	0.00277	Magnesia brick	0.0419
Carborundum	0.00294	Carbon brick	0.1362
Air	0.00335	Graphite brick	0.1474
Mica	0.00335		

The materials named in Tables I to V are those mostly used in the construction of electrical heaters. It is not to be implied, however, that this list is by any means complete. As previously stated, the knowledge of the properties of the electrical and thermal insulating substances is very limited, especially for high temperatures, and it is therefore advisable to use the utmost care when constructing a new heating device, the requirements of which are somewhat out of the ordinary.

ORDERS AND METHODS OF HANDLING*

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This is the second of a series of articles on the general subject of works management, the first article appearing in the April issue of the JOURNAL. In the present contribution it has been the aim to give an indication of the methods in general use rather than a detailed explanation of the particular routine of some one organization. (Ed.)

ORDERS take a variety of forms—they may be large or small, for special apparatus or standard, for spare parts or for repairs, for material or apparatus made by the company itself or material or apparatus bought outside for resale, and any of them may be for domestic or for foreign trade. In the handling of these orders as many as nine departments of a manufacturing organization may be involved, though their names may vary with different companies—and sometimes one department may have combined in it, the functions of another. These several departments are;—the district sales offices, the sales correspondence department, the credit department, the engineering department, the manufacturing department, including costs, inspection and testing, the storekeeping department, the purchasing department, the shipping department and the treasury department. The traffic department might also be added to the list as it is its duty to make contracts or agreements with various transportation companies for the handling of the company's shipments for certain periods of time as well as to trace occasionally delayed or lost consignments, to follow rush shipments, etc. All of these departments, with the exception of the district sales offices, are generally located at manufacturing headquarters, or in other words, at the works.

All correspondence with customers, both before and after the taking of an order, is handled, as a usual thing, by or through the district sales offices, these being therefore the first link connecting the customers and the company together. The district sales offices in turn, carry on all of their correspondence with the sales correspondence department which, therefore, becomes the second link. Perhaps in none of the departments is there a greater amount of common sense required and possibly less set rules to be guided by, than in the sales correspondence department of any large company. It must be the completest kind of an information bureau,, supplying as it does not only the district sales offices with every variety of detail regarding the company's apparatus, so that sales may be facilitated, but after sales have been made, supplying the several other departments with necessary instruction, the engineering department with specifications from which manufacturing information may be prepared, the manufacturing department with dates for shipment, advice as to bonus or penalty, etc., the district sales offices with word as to the progress being made towards completion of orders and so on. In addition to these functions, it is this department which is primarily responsible for the stocks of finished apparatus carried by a company, so that it must be able to anticipate the trend of the market—stocking up on apparatus to meet requirements when business is increasing, discounting in turn dull markets by allowing stocks to become depleted so that the company will not have a large amount of capital tied up, when perhaps it can least be afforded; and seeing at all times that apparatus in stock is sold and not allowed to become obsolete through the bringing out of new standards. It is, of course, not to be expected that the sales correspondence department can accomplish unaided all of the duties enumerated, and accordingly other departments are called upon from time to time to supply such special items of information as may be necessary. The divisions of a department of this kind are purely local and have little or no significance outside of a particular company. In one concern the divisions may be called domestic and foreign—in another, they may be mail order, cash sales, etc., and in another, such as an electrical manufacturing concern for example, they may be railway and lighting, industrial and power, detail and supply, export, repair.

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*Taken in part from the author's paper read at the meeting of The National Tool Builders' Association, Atlantic City, N. J., May 19, 1911.

Contracts for apparatus usually require not only the signatures of the customer and the salesman but are so worded that they do not become valid until countersigned by an executive officer of the company. They are therefore forwarded by the district sales offices to headquarters where practically the first step is for the credit department to investigate the financial standing of the customer in order to safeguard the company against loss. If the replies to their inquiries are satisfactory, an executive officer then formally approves the contract by attaching his signature to it. Contracts are usually signed in duplicate, one copy being returned to the customer through the medium of the sales correspondence department and the district sales office, the other being filed with the auditor. Of course, where the contract is a small one, formality of this kind may be dispensed with, the feature of looking up the customer's financial standing being then delegated to the district sales office. After the approval of the contract, the sales correspondence department next itemizes the apparatus and parts called for, listing them on regular printed forms, and giving to each contract a serial number for reference purposes. Copies are sent to the departments interested, including the storekeeping department, the fourth in the chain. The individual items are scrutinized by the storekeeping department to see if the required materials are available for this particular contract or whether it will be necessary to order them. It will readily be appreciated that some systematic way exists for determining this, and, in general, it is accomplished through the medium of a record somewhat like that illustrated by Fig. 1 and which forms part of a series of loose leaf ledgers—these ledgers may, of course, be carried in card form, if preferred. This sheet is divided into main parts, the first embracing columns for recording the quantity ordered from time to time by the storekeeping department for stock, also the quantity required to fill each contract as it is received, the difference between these two items being the balance available (but not necessarily in stock) to apply on further contracts as same are received. The other main division of this ledger sheet includes

2" x 24" x 25" Hone Finished Marble

ORDERED			REQ. BY SPEC.		BAL. AVAIL.	RECEIPTS						ISSUES					IN STOCK
DATE	REQ	QU.	ORD. NO.	QU.	QU.	DATE	REQ.	QU.	PR. EA.	COST		DATE	S. O. NO	QU.	COST		
1910						1910						1910					
Jan'y						Jan'y						Jan'y					
1	1659	50			50	25	1659	10	5.00	50	00						10
2			340990	10	40	27	1659	20	5 00	100	00						30
3			350110	5	35	31	1659	20	5.00	100	00						50
4			360111	1	34							25	340990	10	50	00	40
5			361110	2	32							27	350110	5	25	00	35
6			340180	7	25							27	360111	1	5	00	34
10	1680	25			50							27	340180	7	35	00	27
12			341460	1	49												
"			340809	2	47												
13			360110	3	44												
14			370118	4	40	Feb'y						Feb'y					
15			370121	20	20	6	1680	10	5.00	50	00						37
"	1710	30			50	10	1680	15	5.00	75	00						52
												10	370121	20	100	00	32

FIG. 1—A FORM OF STOREKEEPER'S RECORD OF STOCK AVAILABLE AND ON HAND

columns for recording the actual receipts of the material in the storerooms, also the issues as they are shipped from the storerooms either into the factory or to customer, the difference between these items being the quantity left in stock. A record such as this is applicable to items of all kinds whether finished apparatus or raw material and is thus employed in the storekeeping department for practically all materials, though it may be modified to some extent in connection with simple items like copper wire and sheet steel as well as for nuts, bolts, washers, screws, rivets, etc. For materials which are used in large quantities and the unit cost of each of which is so inconsiderable, it is not necessary or practical to use quite the same scheme as that used with more valuable materials. These are, therefore, not checked on the ledgers by individual orders but are simply issued in quantities to the manufacturing department by the stock-men of the storerooms; who from time to time send statements to the storekeeping department of the total withdrawals to date and these totals are checked against the various other columns as before.

In the case of certain items like copper, for example, it may be highly advisable under special conditions to depart from the routine just dscribed. Suppose, for instance, there are well defined reasons for believing that copper is to take a decided drop in price, the purchasing department so advises the storekeeping department and the quantities usually carried as availables are allowed to run away down. When the opportune moment arrives, a single large order covering perhaps six months or a year's supply may be placed. The available supply thus becomes as much higher than usual as before it was lower. In such cases delivery can generally be specified as being wanted in monthly, quarterly or other installments, if desired. It must be understood that the storekeeping department in placing their orders, buy the materials either from the works or from outside firms. In the latter case, requisitions are placed with the purchasing department (this being the fifth link in the chain) who in turn buy the materials to the best advantage wherever this may be done. To assist the purchasing department, it is desirable not to specify materials with "trade" names, as this generally ties one up to a fixed price and eliminates competition. So a quality is sometimes specified instead, as for example, black insulating paint, grade "A." The purchasing department can then turn to a key which they have, explaninig what grade "A" means, and on so doing, find that paint of this kind and quality may be purchased from several firms from whom prices are therefore obtained before the order is placed.

Sometimes, when apparatus or material is to be purchased outside and shipped direct to the customer without entering the works in any way, the sales correspondence department may, in order to facilitate matters, communicate with the purchasing department direct, thus eliminating the storekeeping department entirely.

All material as received is checked for quantity and quality and all bills for purchases must, before payment, be O. K'd not only for quantity and quality but for unit price, as well as for total value, thus showing the figures as listed to have been correctly multiplied, added, etc. Material not in stock and to be made in the works is ordered by the storekeeper on what are called shop, stock or store orders which may take a variety of forms. In general, these contain the number of the order, a brief description of the material wanted, the date of entry of the order, the date required for completion, and so on. Copies of these orders are issued to all departments interested. Manufacturing information is, of course, necessary from the engineering department (which is the sixth link in the chain). However, where apparatus has become standardized, the routine work of supplying such information to the manufacturing departments may be very much reduced by having it issued once for all in permanent form. When this is done, the orders as issued by the storekeeping department then bear some key, usually a serial or style number, by means of which the manufacturing departments (these forming the seventh link) can refer to such information already at hand and commence work at once, if advisable, without the necessity of receiving instructions from the engineering department. When the apparatus has not been standardized, however, the engineering department then outline the designs, which are next worked out in detail by the drafting department, this latter being usually considered as a part of the engineering department. In these designs every effort is made to make use of existing patterns, dies, jigs, tools, standard finished materials such as screws, nuts, bolts and washers, raw materials such as standard sizes of sheet metal, wire, bars, etc. When it is necessary to make new patterns the question must be decided (usually by the manufacturing departments) as to whether these shall be of wood or of metal. In the case of new dies, it is a question whether these shall be index or compound and sometimes the element of time may be the deciding factor.

On new work it is often impossible to send all information to the manufacturing departments at once, so the items requiring the most work on them are sent in first and the others as rapidly as possible thereafter. At such times information is likewise sent to the storekeeping department so that their end of the order may be properly taken care of. This manufacturing information consists of drawings and material specifications, or bills of material. It is well worth while to spend a moment or two in a closer examination of the general scheme of compiling such data. Formerly it was the custom in most concerns to make almost a complete set of drawings for each order and without very much attempt to see to what extent parts of drawings already in existence, could be used. From these drawings, each of which was quite elaborate, material specifications or bills of material were written up, listing all of the materials required to build the apparatus shown on the drawings. Gradually, however, apparatus that might be called quite special when finally finished, was found to have an increasing number of parts common to other pieces of apparatus, so the idea was slowly evolved of having a lesser number of assembly drawings and an increasing number of elemental drawings. In this way many elemental drawings can be used over and over again and a considerable saving, therefore, effected in the work of the drafting and other departments.

When a new order is sent to the various manufacturing departments, the orders already on hand are carefully looked over by them to see if there is anything already promised which is at all likely to prevent the date of shipment asked for on the new order, from being kept. If there is, every effort must be made to rearrange the various orders so as to remove any interference; but, if there still remains a conflict, then the sales correspondence department is usually called in to see which orders shall be given preference, referring the matter, if need be, to the district sales office most interested.

Before proceeding further, it will be necessary to consider the physical arrangement of the manufacturing departments if one is to appreciate, even faintly, the tremendous amount of thought and effort regularly expended upon these departments with the sole aim of handling orders expeditiously and economically. There may be said to be two general methods of laying out a works, either by arranging the equipment on the basis of tools and processes, or on the basis of product; sometimes both of these schemes may be combined. It will be found almost invariably that in the original design and layout of manufacturing concerns of small and medium size, the tool equipment has been arranged so that similar tools are grouped together, and, therefore, operations of a like kind, such as milling, planing, drilling, screw machine works, etc. The reasons for this are:—

1—That for each of the principal machining operations there is frequently but a single expert, and in order to make use of his talent, no other scheme is permissible.
2—The centralizing of machines of a kind tends to decrease the number required for a given output. As a result of these there follow logically:—
3—Accuracy and speed in workmanship.
4—Uniformity in methods.
5—Economy in floor space.
6—Minimum distribution of power.

An arrangement of this kind is called departmentalization on the basis of equipment. Under this method of production, a shop may be said to be divided into two portions, "feeder" and "assembly" sections respectively, the feeder sections making the parts from the raw materials and delivering them either to the storerooms or to assembly sections where they are assembled into the complete apparatus preparatory to test and shipment. There will in general, be a number of feeder sections, entirely independent of one another and there may likewise be one or more assembly sections. A production, planning or routing department usually determines the manner in which orders are to be brought through, arranges delivery dates, keeps track of the orders as they progress through the shop and exercises general supervision over production.

In the departmentalization of a works on the basis of product, the apparatus is first segregated into groups or classes. The works are then divided into a certain number of more or less separate manufacturing departments and one or more groups of apparatus assigned to each department for manufacture.

In any growing manufacturing concern with a diversity of product there comes a time when the advantages of the former arrangement are more than offset by the difficulties incident to its successful operation. The increase in volume of semi-finished parts passing from feeder to assembly sections, with the accompanying increase of clerical and other work and the multiplication of foremen and superintendents concerned in the manufacture of any one class of product, result in delays and increased expenses of various kinds which cannot be overcome, nor can the recurrence of them be prevented. Perhaps the greatest drawback of such a scheme is the inability to fill orders promptly. This is especially apparent during periods of business depression when quick delivery is of larger importance than at any other time. The amount of stock on hand is then usually lowest and accordingly a larger percentage of apparatus must be built from the ground up to fill orders. Under these circumstances, it becomes imperative to place all so-called "rush", "forfeiture" and other orders of a like nature in a class by themselves and to conduct them personally, as it were, through the shop. In the doing of this, though, other orders are relegated to the background with consequent disastrous results, particularly in the matter of dissatisfaction on the part of the customers for whom such orders are intended. Of course, the greater the volume of these special orders, the greater the ensuing confusion and delay in connection with other orders, so that this method of procedure is not a solution but simply a makeshift, a temporary expedient to be abandoned as quickly as some more rational method presents itself. Another vital difficulty, perhaps equal in importance to that already mentioned, is the matter of divided responsibility, no one individual being responsible for any complete piece or class of apparatus. Such being the case, it is exceedingly difficult even to make an attempt to ameliorate or to improve conditions which are known to need attention, for the reason that there seems to be no proper place at which to commence the betterment work. As a result of these conditions and without going any more minutely into an analysis of the difficulties, it is reasonable to assume that in consequence of shipments being delayed and responsibility divided, "work in progress" and both raw and finished stock will be large, and such proves to be the case.

In the company with which the writer is connected it became recognized that methods of manufacture which had in the past been satisfactory, were proving inadequate to handle the growing volume of business. After thoroughly investigating the matter, it was deemed advisable to modify the original scheme of manufacturing so as to make it lean more strongly towards manufacture on the basis of product, that is, to divide the plant into a number of separate units, as self-contained as the nature of the work of each permits, and treat the units like independent factories, as it were, housed together under the same roof for mutually advantageous purposes, yet buying from and selling to one another at cost, their various commodities as circumstances made desirable. A scheme of this kind naturally causes a number of duplications of organization and equipment. While this is so, it does not necessarily involve any material increase in either, since the change is more in the nature of a rearrangement of the existing equipment and organization, with the addition here and there of a few tools which under the original plan, were used in common by two or more departments. Even this may be avoided to some extent by assigning such tools to the department requiring them most and permitting the other departments to have their work done on requisition.

In introducing this scheme in the East Pittsburgh Works, (and the Electric Company is being taken simply as typical of other large manufacturing establishments having a wide range of products), it was deemed wise as a precautionary measure to put it into effect in but one department only, further progress along this line to be dependent upon the results obtained in it. This was accordingly done and with very gratifying results, almost from the commencement. It was found as anticipated, that among other advantages, shipments were facilitated and work in progress and stock decreased, all to a very marked degree.

Comparing the routine in this particular department under the original and the modified plans, in the original the work was performed by 22 sections located in 13 independent departments; in the plan as modified, the same work is done by 13 sections in 7 independent departments. But this by no means emphasizes the difference even in the routine, for the reason that under the modified plan, authority for an entire line of apparatus is vested in a single individual, who, therefore, is enabled to exercise his discretion as to the raw and partly finished items to be carried. By a judicious selection of these, he has at all times a certain amount of stock on hand and is thus to a large extent independent in the matter of deliveries on other sections outside of his authority which supply him with materials. In consequence of the excellent showing made in the department selected for trial, departmentalization on the basis of product was gradually extended throughout the plant and though not yet perfect the general results have been a confirmation of those obtained in the department in which the scheme was first tried.

Of course, it is hardly practical to carry this departmental idea into all sections; for example, in pattern shops and founderies, or in certain other places where either the work or the equipment is very special; neither is it wise to include such operations as disc grinding or polishing on account of the deleterious effect of the dust and fumes on other machines in the vicinity, though certain work of this kind may be done in some of the departmentalized sections where facilities for carrying off the dust and fumes can be provided; it is, however, possible to departmentalize a section without necessarily changing its geographical location, simply by assigning a certain proportion of the floor space and the tool equipment in it, to each departmentalized unit.

As at present arranged, there are in the Electric Works eight fairly self-contained departments, as follows:—

1—Railway, mining and crane motors.
2—Power—for large generators and motors.
3—Control—for railway and industrial control apparatus.
4—Detail—for switchboards and accessories.
5—Small motor—for small power motors.
6—Transformers.
7—Locomotives.
8—Industrial—for medium sized motors.

Besides these, certain "feeder" sections still continue:—coils, punchings, blacksmith, cabinet and pattern-making, screw machine, foundries, etc.

With respect to the screw machine section, it may be stated that this has been departmentalized to some extent, though the greater portion, for the manufacture of such parts as are made in large quantities and carried in stock by the central stores, remains unchanged, because considered as a self-contained unit supplying storeroom stock.

Summarizing the various advantages of departmentalization on the basis of product, they may be said to include:

1—Centralizing of authority in the production of each class of apparatus.
2—Decrease in time required to fill orders.
3—Increase of output in a given period.
4—Decrease in work in progress and in stock.
5—Saving in floor space.
6—Decrease in handling of materials.
7—Decrease in clerical labor.
8—Decrease in indirect expense or overhead burden
9—Increase in individual initiative.
10—Healthy competition between similar sections and departments.

It will be seen from the preceding how a growing concern with an ever increasing variety of product may change from one distinct scheme of manufacturing to another equally distinct, both nevertheless being equally effective within their respective limits. For a manufacturing concern with a thoroughly standardized line of products, however, departmentalization on the basis of tool and process equipment, is almost invariably the rule.

If an order is to be handled properly it is, of course evident that the work connected with it must be intelligently mapped out; that is to say if the apparatus is to be built according to regularly prepared designs and in a given time, with the ultimate idea of satisfactorily meeting all requirements including the making of a fair profit, regular methods of procedure with respect both to the labor and the material, must be followed. To those who are not already familiar with the details of such work, it may come as somewhat of a surprise to learn just how closely every item of labor as well as material can be and is actually analyzed and followed up in every up-to-date manufacturing establishment.

It must not be supposed that apparatus is regularly built from the ground up on its own order—such is perhaps the exception rather than the rule. To facilitate production, parts of apparatus are carried in stock in a more or less finished condition, so that the average order for a complete piece of apparatus is frequently but an assembling one. In other words, when a contract is received and an order entered on the manufacturing departments by the storekeeping department for the apparatus, the parts are not necessarily made on this particular order but are largely drawn from stock, that is, from the storerooms, where they are regularly carried either in a wholly finished or a partly finished condition, whichever will give them the greatest degree of flexibility. They are then assembled on this order and sent to the shipping department (this being the eighth link in the chain). The ninth and last link is the treasury department to whom is paid the price of the apparatus by the customer.

There is one class of orders which, as a rule, is handled quite differently from every other kind—these are repair orders. In general, the assumption is made that the customer is in urgent need of the apparatus which should, therefore, be repaired and returned to him at the earliest possible moment. To carry out this idea frequently necessitates a violation of routine, but it pays nevertheless to do so. Another class of orders which is considered somewhat in the same way as repair orders (though of course not to the same extent) are foreign orders, especially to distant ports—this is on account of the time between the departure of vessels being considerable, sometimes a month or two, so that missing a scheduled steamer may become a serious matter. It goes almost without saying that forfeiture orders are always in this preferred class.

The stock of all manufacturing concerns may be separated into three parts—raw materials, work in progress and finished apparatus or parts, though this scheme may not always be carried out in practice. Where it is in effect, however, and separate accounts maintained, the raw materials when received at the works and turned into the storerooms are charged against the raw materials account and when they are in turn drawn out of the storerooms by the manufacturing departments, this raw materials account is credited, while work in progress becomes debited. When the apparatus is finally finished and shipped into the warehouse, the work in progress account is credited and the finished apparatus account becomes debited, and finally when the apparatus is shipped to the customer the finished apparatus account is credited and the customer is debited. All of these accounts of course mean capital tied up temporarily as money has been paid out both for labor and material and sometimes the amounts involved run into tremendous figures.

Generally speaking, the raw materials should in theory arrive at the works just when needed, neither sooner or later. Similarly with the stock of finished apparatus, this should be shipped to the customer as soon as completed; or if it is a quantity for stock which is completed at one time, the last of this quantity should be sold and shipped to customer, just as the next quantity is completed and turned into the warehouse, the idea being to fill customer's requirements at all times from stock and not keep them waiting, yet to have no surplus on hand. Of course, it is absolutely impossible even to approach this ideal condition and always have finished material or apparatus ready to ship whenever wanted, yet never to have any raw or finished material on hand when it is not wanted, nevertheless, the ideal condition should be constantly striven for. One way in which the amount of stock is sometimes regulated will be briefly explained.

Assume that the sales correspondence department has decided that in order either to hold a fair share of the trade in certain lines of apparatus or perhaps to increase it, it will be necessary to be in a position to fill customers' orders from stock where heretofore 120 days have been satisfactory in which to make deliveries. One hundred and twenty days are required for two reasons: because the materials have not been carried in stock and it takes an average of 60 days to get them into the works after placing orders and a further 60 days are necessary in which to turn out the finished apparatus. We see, therefore, that even if it were decided to carry the raw materials in the storerooms, the best deliveries of finished apparatus that could be made would be 60 days after receipt of customers' orders instead of 120 days, but this is not good enough. Finished apparatus must be in the warehouse ready to ship on a day's notice. If only the raw materials were to be carried in the storerooms and it required 60 days to turn them into finished apparatus in the warehouse, it is at once evident that a 60 days' supply of such finished apparatus would have to be carried in the warehouse; because for every piece that was shipped to customer, 60 days would be required to replace it. However, a 60 days supply of finished apparatus means perhaps altogether too much capital invested, so the sales correspondence and the manufacturing departments evolve a scheme for carrying, say 30 days supply of finished apparatus in the warehouse and at the same time a stock of certain partly finished parts which are capable of being turned into finished apparatus within 30 days. Comparing now these two schemes, namely, the one in which 60 days supply of finished apparatus is carried in the warehouse with the one in which 30 days supply of finished apparatus is carried in the warehouse, as well as a stock of partly finished parts, it may be seen that there is a marked advantage in the latter over the former. This second scheme manifestly calls for the tying up of a less amount of capital than the first scheme and if it is finally decided to adopt it, a schedule is made out listing the parts that are to be carried in stock as partly finished material. A schedule of this kind is known as a stock specification. Besides tying up less capital, it is also more flexible in that these partly finished parts are frequently available for filling orders for spare parts or for being used perhaps in the building of other apparatus.

THE SPHERE SPARK GAP

S. W. FARNSWORTH

FOR measuring maximum instantaneous values of high voltages a spark gap is commonly used, consisting of two terminals separated by a certain air gap. By calibration, the voltages necessary to break down various separations are determined, thus making the spark gap a secondary standard. The breakdown voltage for a given distance varies greatly for different shapes of terminals, so in making a standard gap the exact shape of terminal must be specified. Until recently sharp needle points have been used almost exclusively. Other than the shape of the terminals such factors as humidity, barometric pressure, temperature, etc., cause variations, and corrections for these are necessary when accuracy is desired.

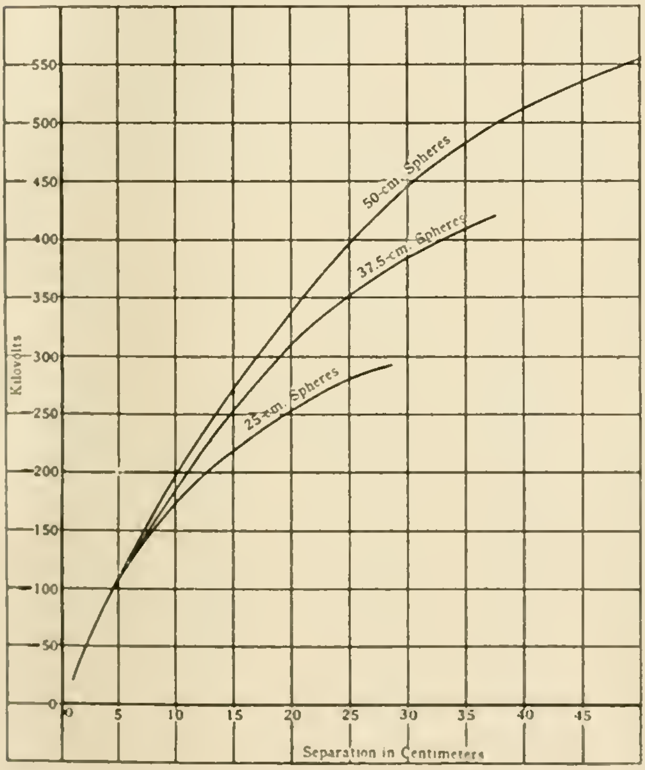

FIG. 1—CALIBRATION CURVES OF SPHERE SPARK GAPS

One sphere grounded. As yet only the 25-cm sphere curve has been actually calibrated up to full diameter separation. For values above 300 000 volts the curves for the 37.5-cm and 50-cm spheres have been derived from the 25-cm sphere curve.

With the higher voltages which have come into use during the past few years, the inconsistencies of the spark gap using needle terminals have been more noticeable and the extreme care which has to be used to obtain consistent and reliable results has caused dissatisfaction with its use. For the past three years, spark gaps having spheres for terminals have been in regular use. These have proven so superior to the needle gap and have given such complete satisfaction that they have been proposed as an A. I. E. E. standard to replace the needle gap in a joint paper by Mr. Fortescue and the author.*

When spheres are used for terminals, breakdown will take place without initial corona, if the separation is not greater than the diameter of the spheres.† The advantage of the sphere gap over other gaps depends upon this absence of corona. In order, therefore, to measure high voltages, large spheres must be used to keep the separation less than their diameter, spheres of 25 cm., 37.5 cm., and 50 cm. diameter being used for ranges of voltages (effective values) from 50 000 to 275 000, 412 500 and 550 000 volts respectively. Other sizes have ranges in proportion. These values are for the case when one end is grounded. A lower limit is placed upon the ranges for these sizes because the distance of separation for voltages below 50 000 are so small, and the air is so highly stressed that any slight defect in the surface of the sphere, or a particle of dirt on the surface, will cause a variation in the breakdown voltage. For the ranges cited these gaps give excellent satisfaction. The breakdown voltage is not affected by humidity, but does vary inversely with the absolute temperature and directly as the barometric pressure. Since consistent results can be obtained with the sphere gap a careful calibration‡ is possible. The results for the 25 cm., 37.5 cm. and 50 cm. spheres, which are the sizes ordinarily used, are given in Fig. 1.

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*See Proceedings A. I. E. E., Feb., 1913, p 301.

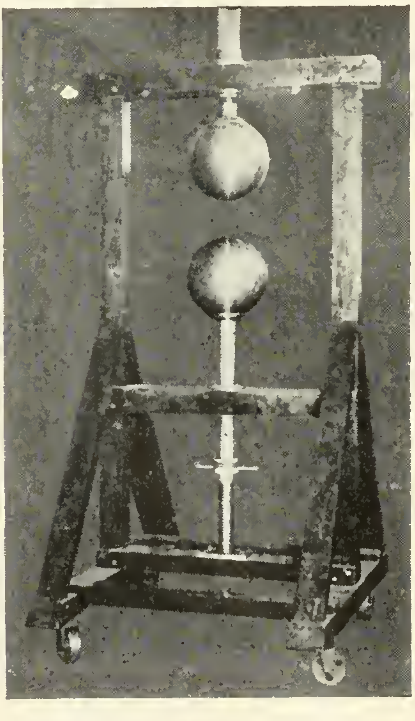

FIG. 2—50 CM. SPHERE GAP

Besides its consistency the sphere gap has a great advantage over the needle gap due to its mechanical construction. Fig 2 shows a 50 cm gap and Fig. 3 gives the dimensions of all three sizes. Being constructed vertically they use very little floor space as compared with equivalent horizontal needle point gaps. The top sphere is stationary but slightly adjustable in height so as to just make contact with the lower sphere when it is set for zero separation. The lower sphere is mounted on a piece of tubing which carries a threaded bushing on its lower end. This bushing works on a carefully threaded rod having a pitch of two per centimeter. The bushing being graduated to fiftieths on its circumference, separation may be measured to the nearest 1/100 cm. directly, thus providing a micrometer adjustment. Being made of large parts the whole arrangement is mechanically strong and the spheres are kept in constant alignment. When mounted on large wheels the spark gap sets are easily portable.

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†Mathematical proof as to why there is no initial corona before breakdown in this case is given by Mr. Alex. Russell in the Philosophical Magazine and Journal of Science, Vol. II., Sixth Series, p. 237.

‡Messrs. Chubb and Fortescue calibrated the sphere gap by a very unique method. See Proceedings of the A. I. E. E., for Feb., 1913, p. 629.

All of the framework is made of wood which has been carefully dried and impregnated with linseed oil. This treatment renders the wood impervious to moisture and thus maintains the high insulation necessary between spheres. The construction of the spheres themselves is of interest. The first ones were made from two hemi-spherical brass castings sweated together and machined. The latest and most satisfactory spheres have been made from two pressed hemispheres, either brass or copper. A shank is attached to one of these by bolts from the inside, the two halves fitted together and the sphere so formed is accurately turned on a milling machine. Brass spheres, after three years of continuous service, show no deterioration of their surface due to arcing. The current which flows on break down of the gap is limited by resistance in series with the gap. About one ohm per volt has been found to be a good value. Eliminating the necessity for renewing terminals and adjusting for zero setting after each breakdown means a great saving in time when many tests are to be made.

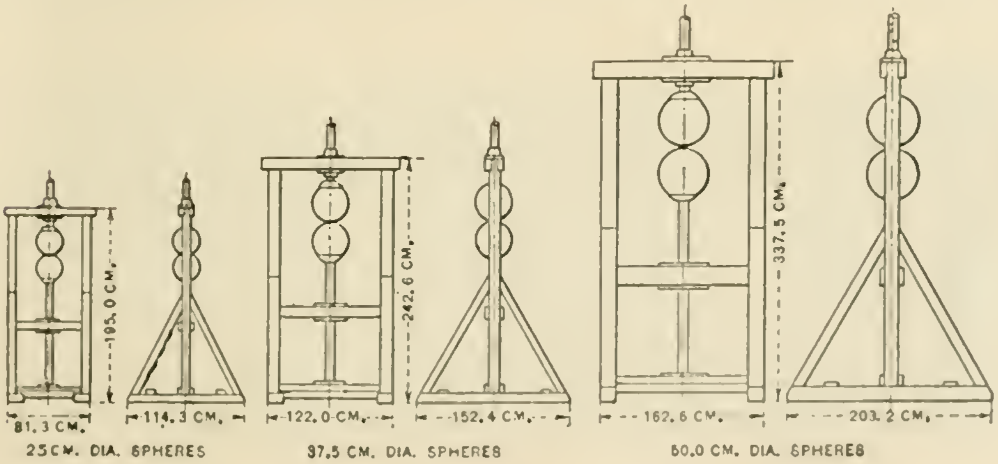

FIG. 3—DIMENSIONS OF 25, 37.5 AND 50 CM. SPHERE GAPS

The use of the sphere gap will permit the direct comparison of results obtained by different experimenters on high voltage work in different parts of the country, and may prove that their results are really in agreement instead of at variance as has so often seemed the case in the past.

DRYING OUT THE DAYTON LIGHTING PLANTS

GEORGE W. CHRISTIANS, E. E.

(Mr. Christians, who is foreman of the general testing department of The New York Edison Company, was sent to Dayton, Ohio, at the time of the recent flood to assist in putting the plants in shape to resume operation. He furnishes herein some interesting comments on the situation, as he found it in the Dayton Lighting Company's plants, which should be of value to other engineers who have similar problems to meet.—(Ed.)

IT may seem rather odd to wash down the windings of a high voltage generator with a hose. Yet this was done with very good effect in the lighting plants of flooded Dayton. The receding waters, in addition to having thoroughly soaked all insulation, left behind a heavy layer of thick slimy mud. The most obvious and actually the most effective way to remove this mud was with a hose, and since the insulation could hardly get any wetter no harm was done by the water. The extent to which this mud clogged things up and the difficult places to which it gained entrance, are almost inconceivable.

An idea of the amount of material held in suspension by the water can be gained from the fact that a number of meter and Tirrel regulator cases on the switchboard at the Third Street plant, on which the high water mark could be seen about six inches from the bottom contained about a half an inch of mud. Still there were exceptions. When the end bells were removed from the windings of a 6 000 kilowatt, 2 200 volt, horizontal Westinghouse turbo-generator, the surfaces appeared dry and the parts of the windings immersed were still covered with the dust collected in ordinary operation, and appeared exactly like the parts which were untouched by the water. Yet this machine was under water nearly to the center of the shaft, and tests showed the insulation to be saturated. The probable cause for this absence of mud is the fact that the water in order to reach the winding had to come up through the basement which formed a depository chamber for the material in suspension, leaving the water clear when it reached the generator.

The water rose in the Third Street plant about four feet above the engine room floor, so that the horizontal turbo-generators were wet to about the center of the shafts and were unbalanced; making it necessary to dry out the water not only for insulation purposes, but to restore their balance. In the case of a 100 kilowatt, 2 400 r.p.m. turbo-exciter, the drying out had to be continued a considerable time after the machine was electrically fit for service in order to reduce vibration.

Another difficulty encountered in the Third Street plant was in getting steam. The draft flue from the boilers to the stack passes under the boiler room floor and, of course, was full of water. There were numerous leaks into this flue from the other parts of the basement, so that the entire building had to be pumped dry before steam to run the plant could be generated. The steam for these pumps was obtained from one boiler by cutting open the draft duct at the top and allowing the flue gases to escape through the roof.

At the Fourth Street plant, it was found necessary to dry the brush arc machines in an oven. The armatures contained much moisture which could not be reached by electrical heating of the windings, but which readily evaporated when evenly heated. Difficulty was also experienced in drying the field spools of these machines electrically. The difference of potential between the long layers of the cotton covered windings, when enough current to heat them was being passed, was sufficient to set up electrolysis between the layers, with a formation of copper salts, and eventually short-circuit them. These had to be stripped of their outer insulation and partially dried in the oven, then after a final heating electrically, and re-insulating, they were as good as new.

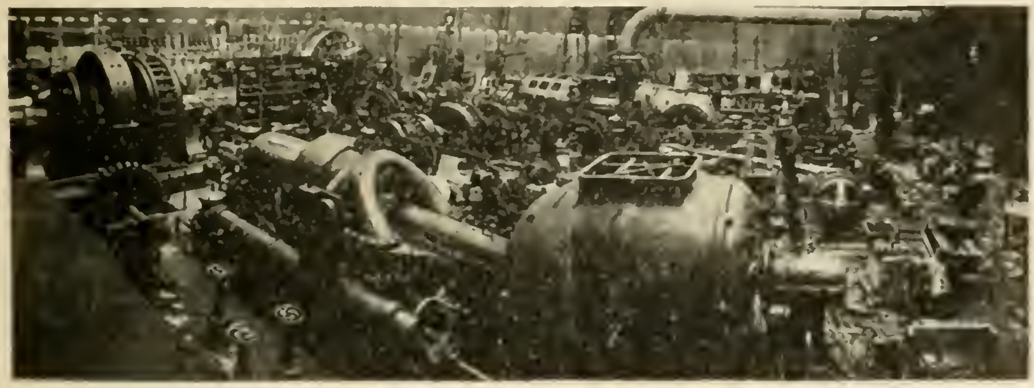

FIG. 1—INTERIOR OF FOURTH STREET STATION DURING CLEANING UP PERIOD
High water mark indicated by dotted line.

The work of restoring the underground and street lighting systems was hampered considerably by natural gas in manholes and cable ducts. The bases of the ornamental lamp posts were often found charged with an explosive mixture which would be ignited when the switch was opened. Great numbers of these ornamental posts were broken off and some even uprooted. An oxyacetylene blow torch was used to weld together the broken ones with very good results. After a coat of paint had been applied no one would know the post had been damaged.

SHOP TESTING OF ELECTRICAL APPARATUS—V

DIRECT-CURRENT MACHINES—SHUNT AND COMPOUND GENERATORS

IN order to give a practical illustration of the methods and processes commonly used in testing direct-current generators, the following actual data from an engineering test of a 2 000 kilowatt, 575 volt, 300 r.p.m., commutating-pole, compound-wound generator are given along with instructions for making such tests.

DETERMINATION OF RESISTANCE AND COPPER LOSS

The resistances of the commutating pole and series fields, and of the armature are determined by the Kelvin bridge method, while the shunt field resistance is measured with the Wheatstone bridge. The values obtained must be corrected to the standard temperature of 25 degrees C. by multiplying the readings by the proper temperature coefficient.* In this particular case, the temperature of the machine was 16 degrees C., for which value the correction coefficient is 1.0355. The armature resistance is generally taken between two sets of adjacent brush-arms, on opposite sides of the armature, and the average of the two readings is taken as the armature resistance. Experience has shown that the average of two readings taken in this way is close to the average between adjacent brush-arms all the way around the armature, and the saving in time, especially where there is a large number of brush-arms, is considerable. Having obtained the standard temperature resistances of armature and field, the copper losses can now be calculated.

TABLE I—COPPER LOSS—DATA FROM TEST.

Resistance at 16 degrees C.		Corrected to 25 degrees C
Armature		
Right,	0.001335 ohms	
Left,	0.001344 ohms	
Average,	0.001339 ohms	0.001387 ohms
Interpole Field,	0.000717 ohms	0.0007424 ohms
Series Field,	0.000421 ohms	0.0004359 ohms
Shunt Field,	11.08 ohms	11.47 ohms

CORE LOSS AND SATURATION

The core loss and saturation may be obtained either by the use of a separate driving motor, or by running the machine without load as a shunt motor. The values obtained by these methods are given in Tables II and III. Wherever possible, however, the use of a separate motor is to be preferred, as more reliable results can be obtained than where the machine itself is run as a motor.

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*As given in the table in the February, 1913, issue of the JOURNAL, p. 154.

Use of Separate Driving Motor—For a successful core loss test by this method all readings should be taken at constant speed, since the power input to drive the machine when it is either accelerating or decelerating is not the same as when the speed is constant.

TABLE II—CORE LOSS TEST.

Use of Separate Driving Motor.

Data from Test

Driving Motor			Generator		
Volts	Amperes	Field Amperes	R.P.M.	Volts	Field Amperes
(1) 500	153	5.0	302	10	0
(2) 500	156	5.0	300	100	2.35
(3) 500	162	5.0	300	200	4.92
(4) 500	171	5.0	300	300	7.62
(5) 500	183	5.0	300	400	11.13
(6) 500	202	5.0	300	500	16.5
(7) 500	209	5.0	301	525	18.5
(8) 500	153	5.0	302	10	0
(9) 500	229	5.0	300	575	24.2
(10) 500	257	5.0	301	625	31.5
(11) 500	297	5.0	300	676	43.
*(12) 500	442	4.95	299	725	59.
(13) 500	153	5.0	302	10	0
(14) 500	143	5.0	302 brushes up		0
(15) 500	199	5.0	300 " "		18.5
(16) 500	22	5.0	Belt off		

*Reading (12) taken with generator self excited.

Calculated and Curve Data from Above

	Increase in Motor Amp.	Kilowatts Core Loss	Field Amperes	Armature Volts
(2—1)	3 times 500 V.	= 1.5	2.35	100
(3—1)	9 times 500 V.	= 4.5	4.92	200
(4—1)	18 times 500 V.	= 9.	7.62	300
(5—1)	30 times 500 V.	= 15.	11.13	400
(6—1)	49 times 500 V.	= 24.5	16.5	500
(7—1)	56 times 500 V.	= 28.	18.5	525
(9—1)	76 times 500 V.	= 38.	24.2	575
(10—1)	104 times 500 V.	= 52.	31.5	625
(11—1)	144 times 500 V.	= 72.	43.	676
(12—1)	289 times 500 V.–42775	= 101.7	59.	725

Decrease in Motor Amp.

(1—14) 10 times 500 V. = 5. kw. brush friction
(1—15) 10 times 500 V. = 5. kw. brush friction
(14—16) 121 times 500 V. = 60.5 kw. friction and windage of outfit

After the test data readings have been corrected to their proper value, find the difference between the driving motor armature current without field on the generator and with the various field excitations. These values, shown in the column marked "Increase in Motor Amperes," multiplied by the impressed voltage on the driving motor armature will give the watts core loss at the various voltages, as shown in the column marked "Kilowatts Core Loss." Reading *12* is taken with the machine supplying its own field current; therefore, the increase in the driving motor input for this excitation will include the total watts used for field excitation; i. e., the terminal voltage (725) multiplied by the field amperes (59). Readings with self-excitation should only be taken when it is impossible to carry the excitation high enough with a separate supply.

TABLE III—CORE LOSS TEST.

Machine Operated as a Shunt Motor.

Data from Test

VOLTS	AMPERES	FIELD AMPERES	R.P.M.
250	288	6.3	302
300	248	7.6	300
400	201	11.1	301
500	180	16.5	299
525	178	18.5	300
575	180	24.3	301
625	188	31.5	299
675	203	43.	302

All brushes up except 10; 5 on 2 arms. 196 brushes total.

VOLTS	AMPERES	FIELD AMPERES	R.P.M.
500	170.5	16.5	300

Calculated and Curve Data from Above Test

VOLTS	KW. INPUT	FIELD AMPERES
250	72.	6.3
300	74.4	7.6
400	80.4	11.1
500	90.	16.5
525	93.5	18.5
575	103.5	24.3
625	117.5	31.5
675	137.7	43.
	Brushes up	
500	85.25	16.5

The brush friction loss is calculated from the difference between driving motor amperes with the brushes up and down. The difference between the driving motor input with brushes up and with brushes down with normal field excitation on the generator should check with the difference obtained when there is no field on the machine. If it does not check, the presence of circulating currents in the armature, caused by the brushes short-circuiting the bars, is indicated.

The friction and windage loss is obtained from the difference between the driving motor amperes with the brushes of the machine under test lifted and the reading on the motor with the belt off.

The method outlined above is sufficiently accurate for commercial testing. When it is necessary to obtain the true core loss without the load losses of the driving motor, calculate the I^2R loss on the driving motor armature from its resistance, and the armature current taken at the various field excitations of the generator. The differences between the I^2R of the armature, with no field on the generator, and the I^2R at the various field excitations are to be subtracted from the core loss, as calculated above, at their respective excitations. The core loss curve is plotted with watts as abscissae and volts as ordinates, as in Fig. 1.

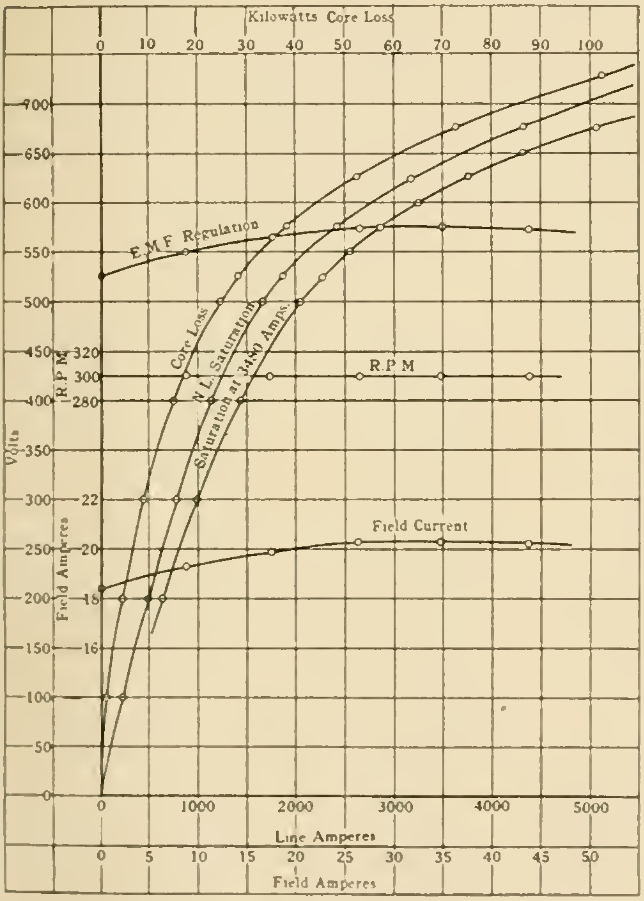

FIG. 1—CORE LOSS, NO-LOAD AND FULL-LOAD SATURATION, AND REGULATION CURVES

With machine driven by a separate motor.

Machine Operated as a Shunt Motor—In this test constant speed is of great importance, as erroneous readings are indicated if the motor is accelerating or decelerating. This means in turn that a source of constant e.m.f., free from fluctuations, is essential. The total brush friction is determined from the formula:—

$$\text{Total brush friction} = \frac{\text{Watts brush friction (obtained from test)} \times \text{total No. of brushes}}{\text{Total number of brushes raised}}$$

$$\frac{(90 - 85.25) \times 196}{186} = 5 \text{ kilowatts}$$

After the readings as shown in Table III have been taken and corrected, the watts armature input may be determined from the armature volts and amperes. This input will include core loss, friction and windage, brush friction and a small I^2R loss in the armature. Since the friction and windage, and brush friction are approximately constant, the only variable is the core loss and by plotting the input of the armature the core loss can very easily be determined. This curve will show the friction and windage and the brush friction where the curve extended meets the base line; since the brush friction is known, the friction and windage can be separated.

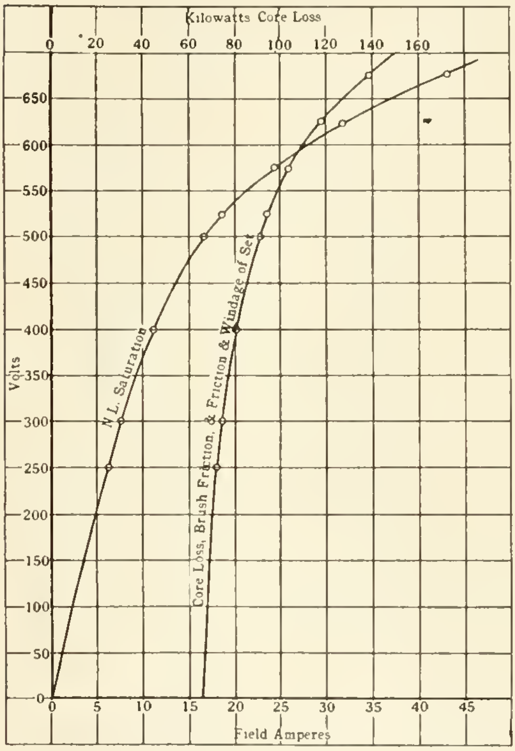

FIG. 2—NO-LOAD SATURATION AND LOSS CURVES

Obtained by Shunt Motor Method.

SATURATION TEST

No Load—The saturation at no-load is obtained from the readings taken during the core loss test. The brushes should be set on the no-load neutral position, and the machine should run at rated speed. In plotting the saturation curve, field amperes should be taken as abscissae, and volts as ordinates, as in Fig. 2.

Full Load—For full load saturation, the machine should be run at rated speed with the same connections as in the no-load saturation test, with the brushes in the full-load neutral position. The series field should be left out of the circuit, and the commutating field in the circuit, with its proper shunt, if one is required. Starting at a value somewhat less than one-half normal voltage with the load adjusted to give full-load current, the voltage should be increased by suitable increments to 20 percent over normal, holding the armature current and speed constant. It may be necessary to excite the shunt field separately to obtain the higher voltage points. Readings, as indicated in Table IV, of terminal volts, armature current, field current and speed are to be taken for each point, and the commutation noted. The curve should be plotted with field amperes as abscissae and volts as ordinates, and the same curve sheet used as for the no-load saturation.

RETARDATION METHOD OF DETERMINING CORE LOSS

Cases sometimes arise where it is inconvenient or impossible to apply either of the methods given above to the determination of core loss. In such cases, the kinetic energy of the machine itself may be used to measure the losses. This method, called the "retardation method," finds its best application with large machines in which the fly-wheel effect is considerable, such as turbo-generators and vertical water-wheel machines, where it is difficult to obtain a separate driving motor. There are several ways in which this method may be applied, most of which are more or less complicated, and this test is not generally to be recommended.*

TABLE IV—FULL-LOAD SATURATION TEST.

Data from Test

Volts	Terminal Amperes	Field Amperes	R.P.M.
200	3480	6.4	299
300	3480	10.0	298
400	3480	14.5	300
500	3480	20.3	301
525	3480	22.5	300
550	3480	25.3	300
575	3480	28.5	298
600	3480	32.0	301
625	3480	37.5	299
650	3480	43.0	300
675	3480	50.6	300

VOLTAGE REGULATION

In order to compensate for line drop, which increases with the load, most direct-current generators are designed to give a slightly higher voltage at full load than at no load. Such machines are said to be over compounded, and the amount of variation in voltage from no load to full load is known as the "compounding" of the generator. The regulation, as defined by the standardization rules of the American Institute of Electrical Engineers is the ratio of the maximum difference in voltage from a straight line connecting the no load and rated load values of terminal voltage, as a function of the load current, to the rated load terminal voltage. The regulation is determined from the curve of compounding, which is, on this account, frequently spoken of as the regulation curve. The compounding of a machine is subject to control; the regulation is not. In general the voltage regulation of direct-current generators is determined as follows:—

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*For a complete description of the Retardation Method see Karapetoff, "Experimental Electrical Engineering", Vol. I, pp. 314-320.

All engine-type generators are assumed to have two percent speed variation from full load to no load; that is, the machine must operate at rated speed at full load, and the no-load speed must be two percent above the full-load speed, speeds at other loads being in proportion. This assumption is based on the fact that the speed of steam engines cannot usually be held constant within closer limits than two percent. Belted and water-wheel generators have constant speed regulation, and all regulation tests should be taken at rated speed over all ranges of load. When generators are part of motor-generator sets, the regulation should be taken as an outfit and with motor running under normal conditions. In commutating-pole machines, before proceeding with the regulation, the current in the commutating-pole windings must be so adjusted that the proper compensation will exist. In most cases no adjustment will be necessary. On account of the effects of residual magnetism, the regulation test must always be made with increasing load, as in the case of the saturation curve, unless otherwise specified. It is usually taken during the continuous temperature test. Connect the machine to the required load as in Fig. 3.

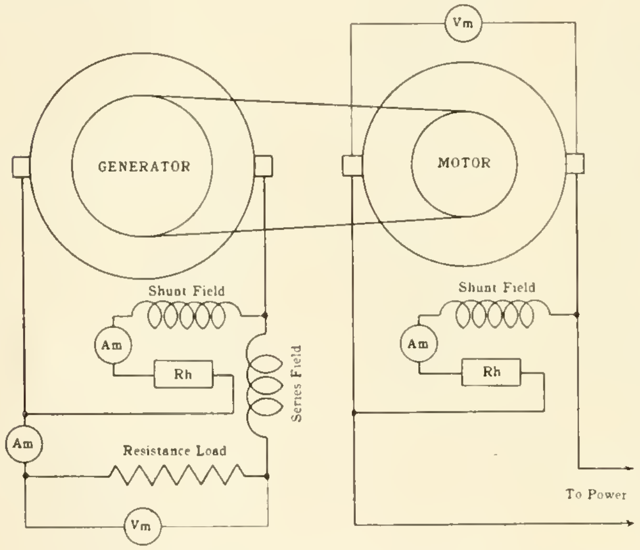

FIG. 3—CONNECTION DIAGRAM OF DIRECT-CURRENT GENERATOR WITH RESISTANCE LOAD

Shunt-Wound Generators—In the case of shunt-wound machines, a different method of defining regulation must be adopted from that used for machines provided with a series winding. The voltage of shunt machines is greater at no-load than at full-load, and the regulation is the amount of increase of voltage from *full-load to no-load*, when the machine gives normal voltage at full-load. For practical purposes, however, it is customary to take a field-current regulation. This is done by holding the terminal voltage constant, and noting the amount of variation in field-current from no-load to full-load. The procedure is as follows:

The brushes are first set in the correct running position, after which the machine is started and run at normal load for an hour or so until the windings warm up. Then the load is taken off, the voltage and speed adjusted to their proper values, and a complete reading of terminal volts, field amperes and speed taken, the commutation being carefully noted. One quarter load should then be put on the machine, the voltage and speed again adjusted, and another set of readings taken. This process should be repeated at each quarter load up to one and one-fourth load.

Compound-Wound Generators—A compound-wound machine should operate from no load to full load at the required voltage without requiring adjustment of the shunt field. The general shape of the voltage regulation curve can be controlled to a great extent on a non-commutating-pole compound generator by the position of the brushes; the closer the brushes are set to the no-load neutral the greater will be the maximum voltage variation, and the farther forward the brushes are moved, the nearer flat the regulation curve becomes and the greater the field current required. Consequently, on account of the better performance, the brushes should be as near full-load neutral as the commutation at no load will permit.

The adjustment of the current in the series field for the required compounding must be made when the field is hot, on account of the difference between the temperature coefficient of copper and German silver or iron shunts. The shunt field resistance must remain constant during this test.

The machine is first started up and allowed to run under load to warm up the windings. On non-commutating-pole machines the brushes should be adjusted to the proper running position during this heating run. After the machine has warmed up, the field is opened and the load taken off. In opening the field circuit a knife switch should be used, and opened slowly, drawing an arc over the break in order to prevent too sudden interruption of the current, as this might induce a destructive voltage in the armature windings. To take the no-load point on the regulation curve the field circuit is closed and the terminal voltage and speed are adjusted to their normal values. Complete readings of terminal volts, field amperes and speed are then taken, the commutation being noted. Full load is now put on the machine, and the speed adjusted to its full-load value. The voltage must be carefully noted; if it is not more than one percent from normal, and the machine has no commutating poles, the correct value may be obtained by shifting the brushes toward no-load neutral if the voltage is to be increased, or toward full-load neutral if it is to be decreased; the amount of shifting of the brushes is, of course, limited by the commutation.

When the voltage is more than one percent low the fields are not strong enough. When the voltage is more than one percent high, a piece of German silver strap is adjusted across the series field to give the correct full-load voltage.

Regulation—Readings for this test should be taken as follows:—

TABLE V—DATA FOR REGULATION CURVE OF COMPOUND MACHINE.

Volts	Terminal Amperes	Field Amperes	R.P.M.
525	0	18.4	300
550	870	19.3	300
565	1740	19.9	300
575	2610	20.3	299
575	3480	20.3	299
573	4350	20.2	299

Amperes shunted from series field, 1150 at full load.
Series drop at full load 1.11 volts.
Shunt, commutating field, none required.
Shunt, series field, 13 grids in multiple.
Series shunt resistance = .000965 ohms.

Take off the load and open the field. If, on closing the field again the no-load voltage is not right, readjust the shunt field rheostat and again go to full load. If the full-load voltage is correct, return to the no-load point, open the field for a moment and if the no-load voltage is still found to be right when the field circuit is closed again take full readings of field amperes, volts and speed. Then by steps of quarter load take points up to 150 percent load, reading each time, line amperes, volts, field amperes and speed, as in Table V, commutation being noted at the same time. At the full-load point, also read the shunted amperes in the series and commutating fields, and the volts drop across each. In measuring this drop, the voltmeter points should be placed on the field terminals and not on any part of the temporary connections. At each point take brush curves, as previously described.

From the above readings, curves of e.m.f., field current and speed should be drawn, these values being plotted as ordinates against line amperes as abscissae. The current in the series field necessary to give any required regulation may readily be calculated in the case of commutating-pole machines from the no-load and normal-load saturation curves. For non-commutating-pole machines, satisfactory results are more difficult to obtain from these curves on account of the shifting of the brushes, and the proper series-field current may be determined experimentally. In the case of the 2 000 kilowatt generator taken as example, the regulation required was 525 volts no load, 575 volts full load.

From the saturation curves, Fig. 1, it is evident that if there were no series field excitation the shunt field current would have to be increased from 18.4 to 28.4 amperes to give the desired increase in voltage, the speed remaining constant. In this case there are 840 turns per coil in the shunt field and three in the series. Since the terminal voltage is increased from 525 to 575 volts, the shunt field current is increased from 18.4 to $18.4 \times \frac{575}{525}$ or 20.2 amperes. The difference between the excitation of 28.4 and 20.2 amperes in the shunt field must be made up by the series field. That is, the current in the series field must be

$$\frac{(28.4 - 20.2) \times 840}{3} = 2296 \text{ amperes.}$$

TABLE VI—OHMS RESISTANCE PER FOOT OF GERMAN SILVER STRAP AND WIRE.

Ohms Resistance per Foot of German Silver Strap and Wire

No.	Thickness	Width 1″	1½″	2″	2¼″	2½″	3″
	.064	.00230	.00153	.00115	.001022	.00092	.000767
	.034	.00433	.00288	.00216	.001925	.00173	.001444
27	.014	.01050	.00700	.00525	.004670	.00420	.003500
30	.010	.01470	.00980	.00735	.006540	.00588	.004900
No. 12 Wire		.0288	No. 17 Wire	.0917	No. 21 Wire	.232	
No. 16 Wire		.0728	No. 18 Wire	.116	No. 24 Wire	.466	

Amperes Carrying Capacity of German Silver Strap
(allowing 2 sq. in. radiating surface per watt loss)

No.	Thickness	Width 1″	1½″	2″	2¼″	2½″	3″
	.064	72	108	144	162	180	217
	.034	52	78	104	117	130	156
27	.014	34	51	68	76	85	101
30	.010	30	44	50	57	74	89

The actual regulation showed 2330 amperes, a sufficiently close check for all practical purposes.*

The above example is probably the simplest that will arise, as the speed is constant and the series drop negligible. For small speed variation the voltage may be considered as varying directly with the speed and proper allowance may readily be made. The series drop is usually negligible except on low voltage machines that are working well up on the saturation curve. It will be found in most cases to be impracticable to calculate this regulation accurately where the ratio of the shunt to series turns is more than 400 to 1.

TABLE VII—CALCULATION OF EFFICIENCY BY LOSSES.

	RESISTANCE AT 25 DEGREES C.	AT 60 DEGREES C.	
Armature	.001387 ohms	.001582 ohms	Total Brush
Series field	.0004359 ohms	.000497 ohms	Area 220½ square inches
Commutating field	.0007424 ohms	.000846 ohms	
Shunt on series field	.000965 ohms		
Series field with shunt (r_3)	.000328 ohms		
Armature, series and Commutating fields, (R)	.002756 ohms		

Line amperes	(I_T)	0	900	1700	2600	3500	4400
Shunt field amperes	(Is)	18.5	19.3	19.9	20.3	20.3	20.2
Armature amperes	(I)	18.5	919.3	1719.9	2620.3	3520.5	4420.2
Terminal volts	(E)	525	548	565	575	575	572
Arm. Ser. and Commutating Fied volts	(e)	0	2.5	4.7	7.2	9.7	12.2
Brush drop	(B)	0	1.21	1.39	1.6	1.8	2.0
Total induced volts	(1)	525	551.71	571.09	583.8	586.5	586.2
Core loss	(2)	28.00	32.60	37.20	40.20	40.80	40.80
Arm. Ser. and Commutating Field loss	(4)	.00	2.33	8.15	18.90	34.15	53.80
Shunt field loss	(3)	9.70	10.58	11.25	11.67	11.67	11.55
Brush loss	(5)	.00	1.11	2.39	4.19	6.34	8.84
Brush friction		5.00	5.00	5.00	5.00	5.00	5.00
Friction and windage		30.25	30.25	30.25	30.25	30.25	30.25
Total losses		72.95	81.77	94.24	110.21	128.21	150.24
Kilowatt output		0	493.2	960.5	1495	2012	2517
Kilowatt input		72.95	574.97	1054.74	1605.2	2140.21	2667.24
Efficiency		0	85.8	91.0	93.2	94.0	94.3

The calculation of the German silver shunt necessary to take care of the excess current should be based on the readings of current and drop taken during the regulation test. These should be checked with readings taken during temperature runs, or at other times. In supplying the shunt to be used on the machine in service, care must be taken that it be large enough to carry the current without overheating.

Table VI gives the resistance and carrying capacity of German silver strap.

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*See also article on "Parallel Operation of Compound Wound Generators," by Mr. C. I. Young, in the JOURNAL for November, 1911, page 974.

EFFICIENCY LOSSES

From the regulation, core loss, and resistance previously taken, the efficiency is calculated. The losses should be calculated at no load and at approximately each quarter load up to 25 percent overload, as shown in Table VII. Where a curve is to be plotted it is not necessary to take the exact line amperes for each fractional load; use the nearest even current value. When the efficiency is required at designated loads it is necessary to use the correct current for these loads.

CALCULATION

Let E = Terminal volts, at load It, as obtained from regulation curve.
It = Terminal amperes.
Is = Shunt field amperes, at load It, as obtained from regulation curve.
I = Total armature amperes $It + Is$, if machine is self-excited.
r = Armature resistance hot or at 60 degrees C.
$r1$ = Series field resistance hot or at 60 degrees C.
$r2$ = Resistance of shunt on series field.
$r3$ = Resistance of series field with shunt = $\frac{r1 \times r2}{r1 + r2}$
$r4$ = Commutating field resistance hot or at 60 degrees C.
$r5$ = Resistance of shunt on commutating field.
$r6$ = Resistance of commutating field with shunt = $\frac{r4 \times r5}{r4 + r5}$
B[*] = Volts brush drop = $\frac{I}{20 \times \text{total brush area}} + 1$
R = Armature resistance (r) + series field resistance (r1, or r3) + commutating field resistance (r4, or r6).

The above formula for R must include the running resistance of all windings in series with the armature.

Then—

$e = I \times R$ (Total drop of all series windings).
Total induced volts = ... $E + e + B$. (1)
Core loss at total induced voltage (1) (From core loss curve). (2)
Shunt field copper loss = ... $E \times Is$. (3)
(This will include the rheostat in the shunt field.)
Copper loss of armature and windings in series with it = $I^2 \times R$. (4)
Brush I^2R loss .... $I \times B$. (5)
Output = $E \times I_t$
Input = Output + Total Losses

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

Total losses = (2) + (3) + (4) + (5) + brush friction + bearing friction and windage if machine is not direct connected to an engine.[†]

The calculations for the machine used as an example are given in Table VII.

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[*] The above formula is an empirical one, obtained from experience. The value of B obtained therefrom should be less than 2. The brush drop may also be taken from standard curves compiled from tests on the particular type of brush used, when these are available.

[†] When the machine tested is part of a motor-generator set, one-half of the friction and windage is usually charged to each unit. In the case of direct-connected, engine-driven units, the friction and windage losses cannot be calculated and are charged to the engine.

When a curve of the above data is desired, the kilowatt input, kilowatt output, separate losses and efficiency are plotted as ordinates against line amperes as abscissa.

Temperature Tests—Temperature runs are made to determine the maximum temperature of the various parts of a machine when operating at certain loads for definite periods. There are, in general, two main classes of such tests:—continuous tests and overload tests. Continuous temperature tests are taken at normal load, and they should be continued for at least one hour after the machine has reached an approximaely constant temperature. Load may be obtained in any convenient manner, but if another machine is used as load, care should be taken that its series field is connected for operation as a compound motor. The time required for reaching constant temperature depends on the type and size of machine, and will usually be between six and twelve hours, enclosed machines taking the longer time. To determine when the machine has reached a constant temperature place several thermometers on the field coils, packed as described in the first article of this series. Readings of the thermometers, and also of the voltage drop in the shunt and series field, should be taken at regular intervals. When these readings have become approximately constant, the test should be continued for at least an hour. This should give the maximum temperature to be obtained on the given continuous load.

The specified overload temperature runs must be put on the machine when it is at ultimate full-load temperature unless special instructions to the contrary are given. This test is made as follows:—

The machine is run on the specified full load, as indicated above, until temperature becomes constant; then the load is increased to the required amount as quickly as possible, and at the end of the specified time the power supply circuit is opened. Care must be taken that overload tests are run for the exact length of time specified, for very often a difference of a few minutes in the running time may mean a difference of several degrees in the final temperatures.

The necessary thermometers should be placed around the machine under test in such positions that the average temperature of the air going into the machine will be measured, and the thermometers for the field coils should be placed so as to determine the running temperature of the coils. The machine is then started, and the load adjusted to the value desired. A complete set of readings of terminal volts, shunt, commutating and series field volts, line and field amperes, speed, commutation and temperature, is taken every hour during continuous load tests and every half hour during overload tests. Noise and brush tension should be noted at the same time. After the machine has been running the required length of time, the power supply circuit is opened and the machine is allowed to come to rest under load. The following temperatures are then taken by thermometer:—Commutator, armature iron, armature copper, shunt field, series field, commutating-pole field, bearings (if with machine) and air (while running).

Take the hot resistance of the following in the order named:—

1—Series field $\left\{\begin{array}{l}\text{With shunt}\\ \text{No shunt}\end{array}\right.$

2—Commutating-pole field $\left\{\begin{array}{l}\text{With shunt}\\ \text{No shunt}\end{array}\right.$

3—Armature

4—Shunt field

The thermometers should be packed on the various parts with warm waste, as noted previously, and great care must be taken to have the bulbs well protected from the air. On the field coils the thermometers should be put between the sections as well as on the outside of the coils.

The temperature should be taken on both the inside and outside of the armature iron wherever possible.

SWITCHBOARDS FOR ALTERNATING-CURRENT POWER STATIONS—V

C. H. SANDERSON

REMOTE MECHANICALLY CONTROLLED SWITCHBOARDS—(Cont.)

THE various possible arrangements of remote controlled switching equipments may be divided into two classes as influenced by the system of connections employed, namely single throw and double throw. Either of these classes may be arranged for wall mounting and may employ the open, semi-enclosed or entirely enclosed structure. Aside from the inevitable circuit breakers, bus-bars and connections, any arrangement under consideration may be influenced materially by the presence of disconnecting switches, fuses and instrument transformers in various parts of the circuit. There is usually much to be gained, not only in economy of cost but also in appearance, simplicity and ease of operation, by selecting just the right arrangement for the conditions obtaining. As an assistance, therefore, to the proper selection of apparatus and lay-out, the accompanying illustrations are presented. While the usual arrangements are fairly covered, it is quite possible that the best arrangement for a particular schedule of apparatus may only be secured by combining certain desirable features from two or more of the arrangements illustrated.

As a further assistance in deciding upon the best arrangement, it may be said that small stations of 2 500 k.v.a. or thereabouts are hardly justified in employing any other than the open arrangement, unless local rules demand that the apparatus be enclosed. Even in this case metal grill work would be much more in keeping and much less expensive than cement structures. When the circuit breakers employed are of the type having one supporting frame for all poles, and it is considered advisable, because of the frequent heavy overloads and short-circuits, to enclose the circuit breakers in cells, the semi-enclosed type is usually chosen. If, under the same conditions, the current capacity is large, or if these circuit breakers are of cell mounting type, it is usually preferable to employ the completely enclosed arrangement.

There is little choice between the horizontal bus-bar and the vertical bus-bar arrangements from an electrical viewpoint, as perfectly satisfactory designs may be obtained from either. From a mechanical viewpoint the vertical bus-bar requires greater height and less width but practically the same amount of supporting framework and the same length of connections. It is obvious that with the open mounted vertical bus-bars, the danger of an arc starting at some point on one of the lower bus-bars and short-circuiting the upper ones is greater than with the open mounted horizontal bus-bars. An arc may start at any point where the insulation to ground fails, where current carrying parts of opposite phase or different voltage are too close together due to faulty erection, to accidental displacement of the members, by short-circuits at some other part of the system or from something falling against or upon the bus-bars or connections. The entirely enclosed structure is the only real insurance against excessive injury to the equipment in case of arcing grounds. In the design of the enclosed structure, it is, however, of great importance, especially when the higher voltages (11 000, 13 200, etc.) common to structural mounting are employed, that openings at different parts of the structure, which might create a path for drafts, be avoided. For the lower voltages, especially 2 200 volts and below, the copper connections are usually very heavy and of large, usually rectangular, cross-section. It is difficult to take such a connection through a wall without considerable expense and local heating of the conductor, except by means of an opening large enough to give sufficient insulation of air around the conductor.

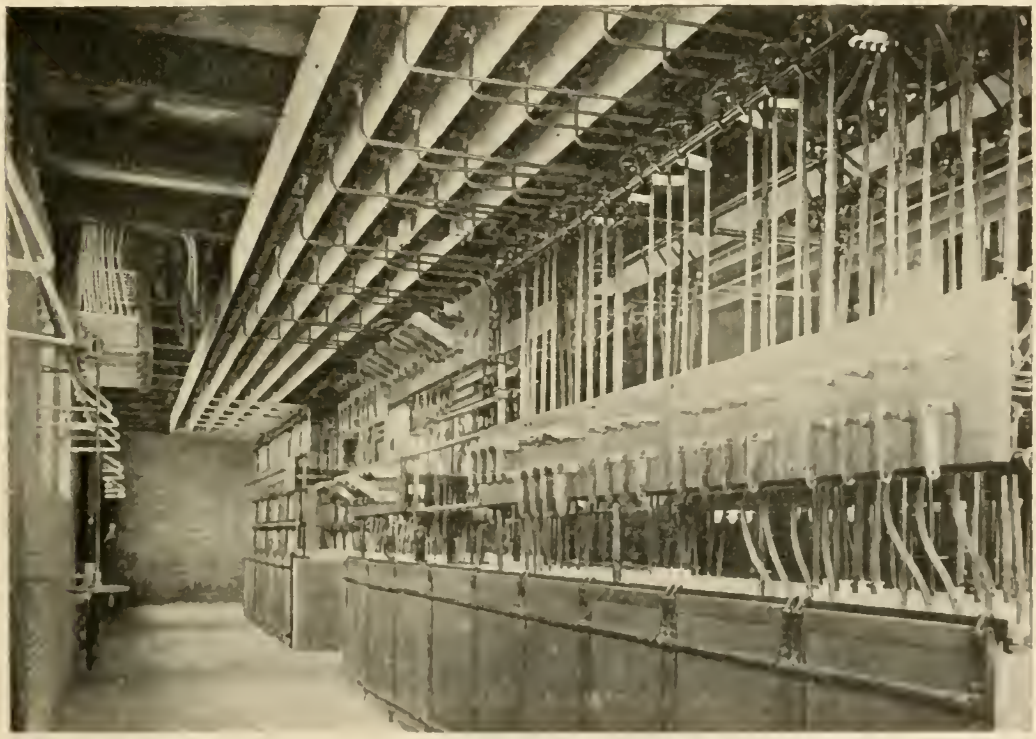


FIG. 37—2 200 VOLTS, TWO-PHASE BUS BAR STRUCTURE, FOR RING BUS
As illustrated in cross section in Fig. 35.

While the enclosed structure has many advantages for installations of medium voltage and current capacity, its use cannot be justified for 440 and 220 volt installations. The danger from arcing is here negligible and the matter of thorough ventilation for bus-bars and connections is of prime importance. This may be appreciated from the fact that the heating on 60 cycle bus-bars of heavy capacity is approximately twice that on direct current.

When choosing an arrangement for a double-throw system, it is highly recommended, especially for stations of medium or large capacity, say 3 000 k.v.a. and above, that the two halves of the equipment be widely separated; by a fire-proof wall if possible. This arrangement both minimizes the possibility of shut-down and permits safe inspection, or work to be done on the idle equipment.

TABLE I—SCHEDULE OF APPARATUS FOR STANDARD PANELS

Three-phase Generator Panel, 16 inches wide.	Feeder Panel, 16 inches wide.
1 Ammeter.	1 Ammeter.
1 Polyphase indicating wattmeter.	1 Three way ammeter switch.
1 Field ammeter.	1 Oil circuit breaker—automatic (single throw or double throw by means of one or two breakers as shown in Figs 1 to 36 incl.)
1 3-way ammeter switch.	2 Relays; single phase, overload, inverse time limit.
1 Synchronizing receptacle.	3 Current transformers. Disconnecting switches where shown.
1 Voltmeter recep., 8 pt.	
1 Field switch.	
1 Rheostat hand wheel.	
1 Oil circuit breaker, non-automatic (single throw, or double throw by means of one or two circuit breakers as shown in Figs. 1 to 36 incl.)	
2 Current Transformers.	
2 Potential transformers with fuses. Disconnecting switches when shown.	

When there are a considerable number of circuits to be controlled, necessitating the use of many circuit breakers, it is necessary to consider carefully the location of the switching equipment in regard to the switchboard panels. The angle at which the mechanism leaves the panel is of no consequence except as it causes interference of the bell cranks and their supports immediately connecting to the control handle. The length of the mechanism and the consequent weight, however, have much to do with satisfactory operation. When two or more circuit breakers are controlled from one panel of a large board it may be necessary even to form the structure in a double row, back to back, somewhat as shown in Figs. 4 and 5 with the bus-bars in the shape of a U, in order to keep the mechanism more nearly at right angles with the board, thus avoiding interference of the bell cranks.

COSTS

Table II gives approximate total costs, exclusive of installa-

TABLE II—APPROXIMATE COST OF SWITCHBOARD PANELS.

Fig.	Cost	*U.B.C.	Amps.	Volts	Kind of Panel	Volts	Amps.	Fig.	Cost	U.B.C.*
1	$ 935	15 500	300	6 600	Generator	2 200	600	19	$ 480	18 500
	1 015	12 500	"	11 000		6 600	300		500	15 500
1	835	15 500	"	6 600	Feeder	2 200	600	19	420	18 000
	855	12 500	"	11 000		6 600	300		390	15 500
2	360	7 800	"	6 600	Generator	440	600	20	340	9 800
	305	9 200	"	2 200		"	1 200		390	9 800
2	260	7 800	"	6 600	Feeder	"	600	20	290	9 800
	255	9 200	"	2 200		"	1 200		340	9 800
3	1 080	15 500	"	6 600	Generator	2 200	300	21	360	9 200
	915	12 500	"	11 000		6 600	"		310	7 800
3	860	15 500	"	6 600	Feeder	2 200	"	21	260	9 200
	770	12 500	"	11 000		6 600	"		265	7 800
4	340	9 800	600	440	Generator	2 200	"	22	375	9 200
	385	9 800	1 200	"		6 600	"		325	7 800
4	290	9 800	600	"	Feeder	2 200	"	22	280	9 200
	335	9 800	1 200	"		6 600	"		285	7 800
6	340	9 800	600	"	Generator	440	600	24	360	9 800
	385	9 800	1 200	"		"	1 200		410	9 800
6	285	9 800	600	"	Feeder	"	600	24	310	9 800
	330	9 800	1 200	"		"	1 200		355	9 800
7	475	18 000	600	2 200	Generator	6 600	300	25	370	7 800
	490	15 500	300	6 600		2 200	"		320	9 200
7	410	18 000	600	2 200	Feeder	6 600	"	25	275	7 800
	385	15 500	300	6 600		2 200	"		270	9 200
8	350	9 200	"	2 200	Generator	11 000	"	26	695	12 500
	295	7 800	"	6 600		6 600	"		590	15 500
8	250	9 200	"	2 200	Feeder	11 000	"	26	560	12 500
	255	7 800	"	6 600		6 600	"		505	15 500
9	400	9 200	"	2 200	Generator	2 200	600	27	625	18 000
	385	7 800	"	6 600		6 600	300		585	15 500
9	360	9 260	"	2 200	Feeder	2 200	600	27	530	18 000
	345	7 800	"	6 600		6 600	300		470	15 500
10	400	9 200	"	2 200	Generator	2 200	300	28	270	3 000
	375	7 800	"	6 600		"	100		240	3 000
10	355	9 200	"	2 200	Feeder	"	300	28	230	3 000
	345	7 800	"	6 600		"	100		212	3 000
11	275	3 000	"	2 200	Generator	"	300	29	290	3 000
	255	3 000	100	"		"	100		265	3 000
11	215	3 000	300	"	Feeder	"	300	29	250	3 000
	200	3 000	100	"		"	100		225	3 000
12	440	9 200	300	"	Generator	2 200	300	30	425	9 200
	385	7 800	"	6 600		6 600	"		375	7 800
12	345	9 200	"	2 200	Feeder	2 200	"	30	330	9 200
	350	7 800	"	6 600		6 600	"		325	7 800
13	480	9 200	"	2 200	Generator	2 200	600	31	535	18 000
	420	7 800	"	6 600		6 600	300		560	15 500
13	410	9 200	"	2 200	Feeder	2 200	600	31	465	18 000
	405	7 800	"	6 600		6 600	300		440	15 500
15	550	9 200	"	2 200	Generator	2 200	600	33	780	18 000
	445	7 800	"	6 600		6 600	300		800	15 500
15	415	9 200	"	2 200	Feeder	2 200	600	33	705	18 000
	425	7 800	"	6 600		6 600	300		680	15 500
16	700	18 000	600	2 200	Generator	6 600	"	34	490	7 800
	640	15 500	300	6 600		2 200	"		435	9 200
16	585	18 000	600	2 200	Feeder	6 600	"	34	410	7 800
	515	15 500	300	6 600		2 200	"		405	9 200
17	550	7 800	"	6 600	Generator	6 600	"	35	710	7 800
	500	9 200	"	2 200		2 200	"		675	9 200
17	475	7 800	"	6 600	Feeder	6 600	"	35	635	7 800
	475	9 200	"	2 200		2 200	"		600	9 200
18	915	18 000	"	2 200	Generator	11 000	"	36	1 240	12 500
	825	15 500	"	6 600		6 600	"		1 150	15 500
18	800	18 000	"	2 200	Feeder	11 000	"	36	1 015	12 500
	715	15 500	"	6 600		6 600	"		940	15 500

*The column marked U. B. C. gives the ultimate circuit breaking capacity of circuit breakers set for instantaneous trip. The above table will permit of obtaining the approximate cost of a complete switchboard. The cost for exciter panels may be taken from pages 163 and 173 of the February issue.

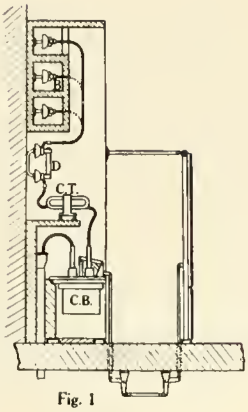


Fig. 1

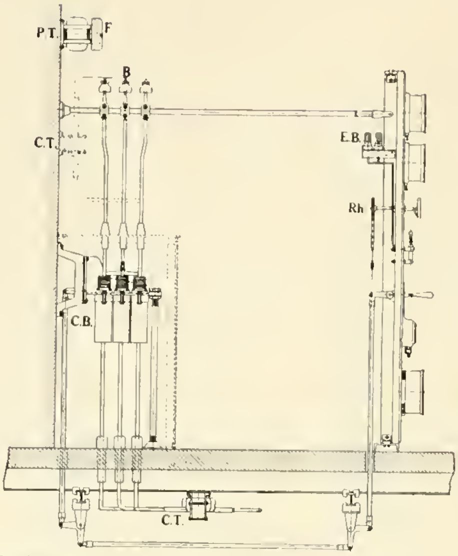


Fig. 2

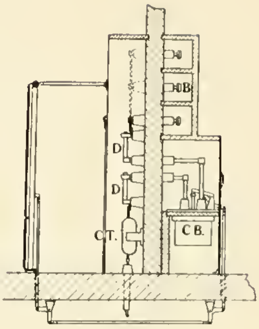


Fig. 3

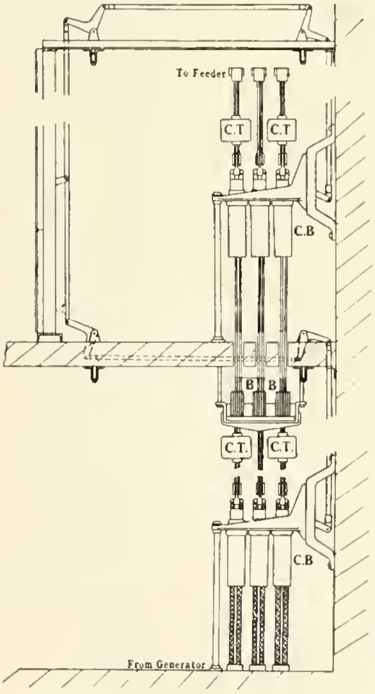


Fig. 4

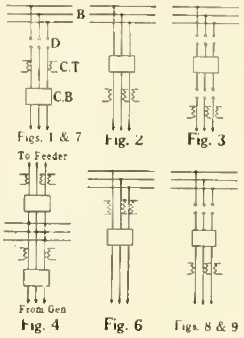


Fig. 5

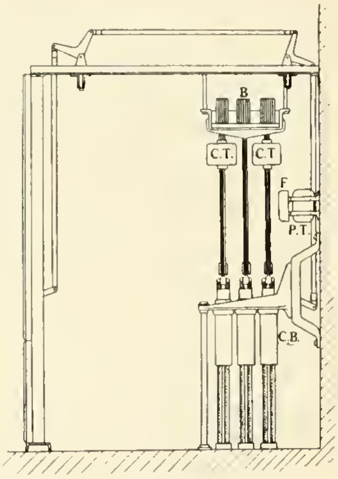


Fig. 6

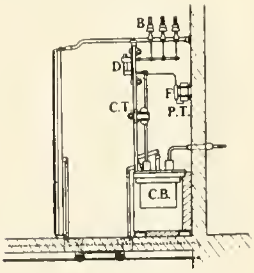


Fig. 7

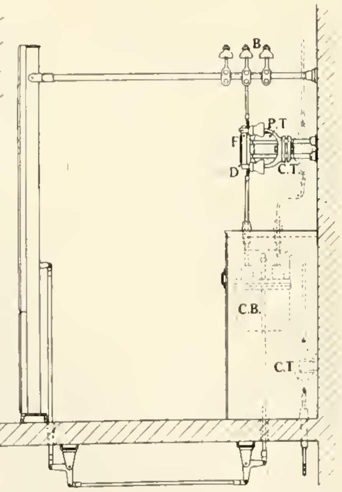


Fig. 8

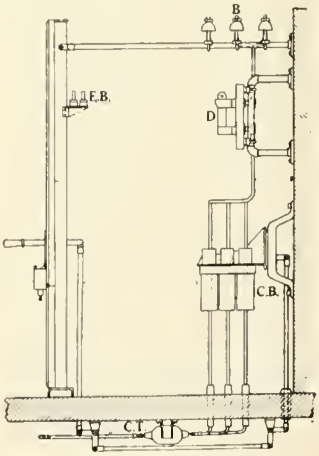


Fig. 9

FIGS. 1 TO 9—SINGLE BUS, WALL MOUNTING ARRANGEMENTS

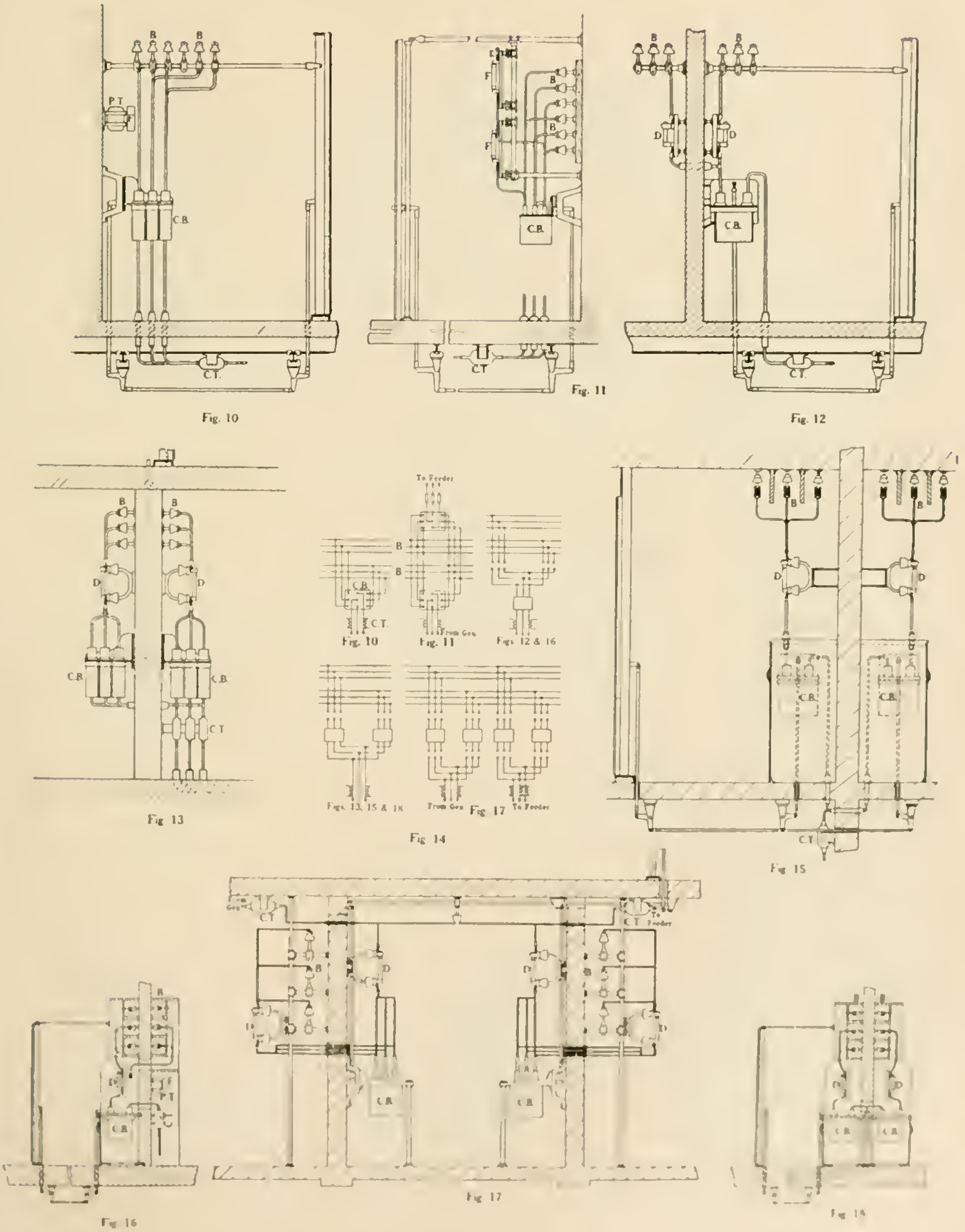
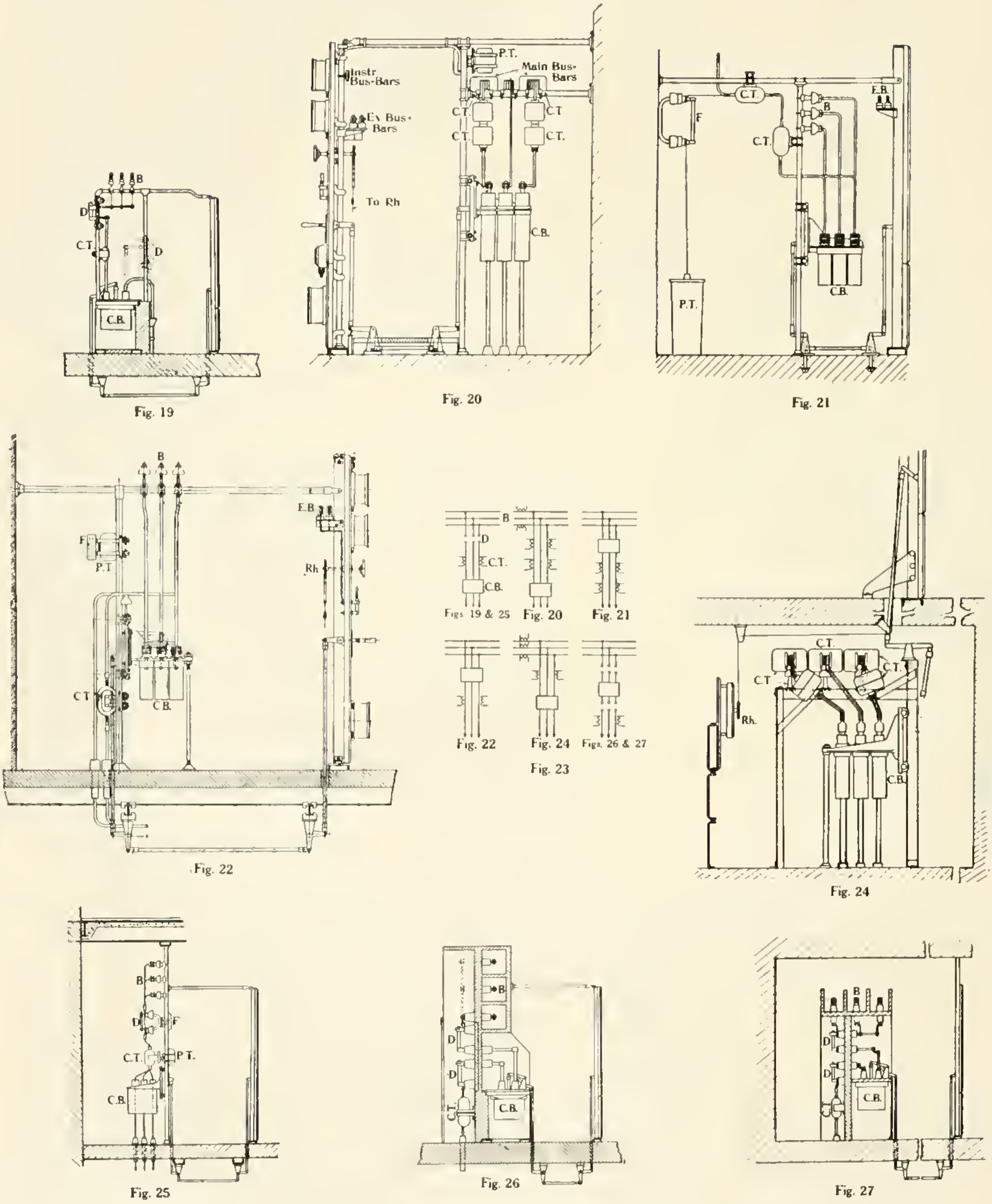


Fig. 10 Fig. 11 Fig. 12 Fig. 13 Fig. 14 Fig. 15 Fig. 16 Fig. 17 Fig. 18

FIGS. 10 TO 18—DOUBLE BUS, WALL MOUNTING ARRANGEMENTS



FIGS. 19 TO 27—SINGLE BUS, SEPARATE MOUNTING ARRANGEMENTS

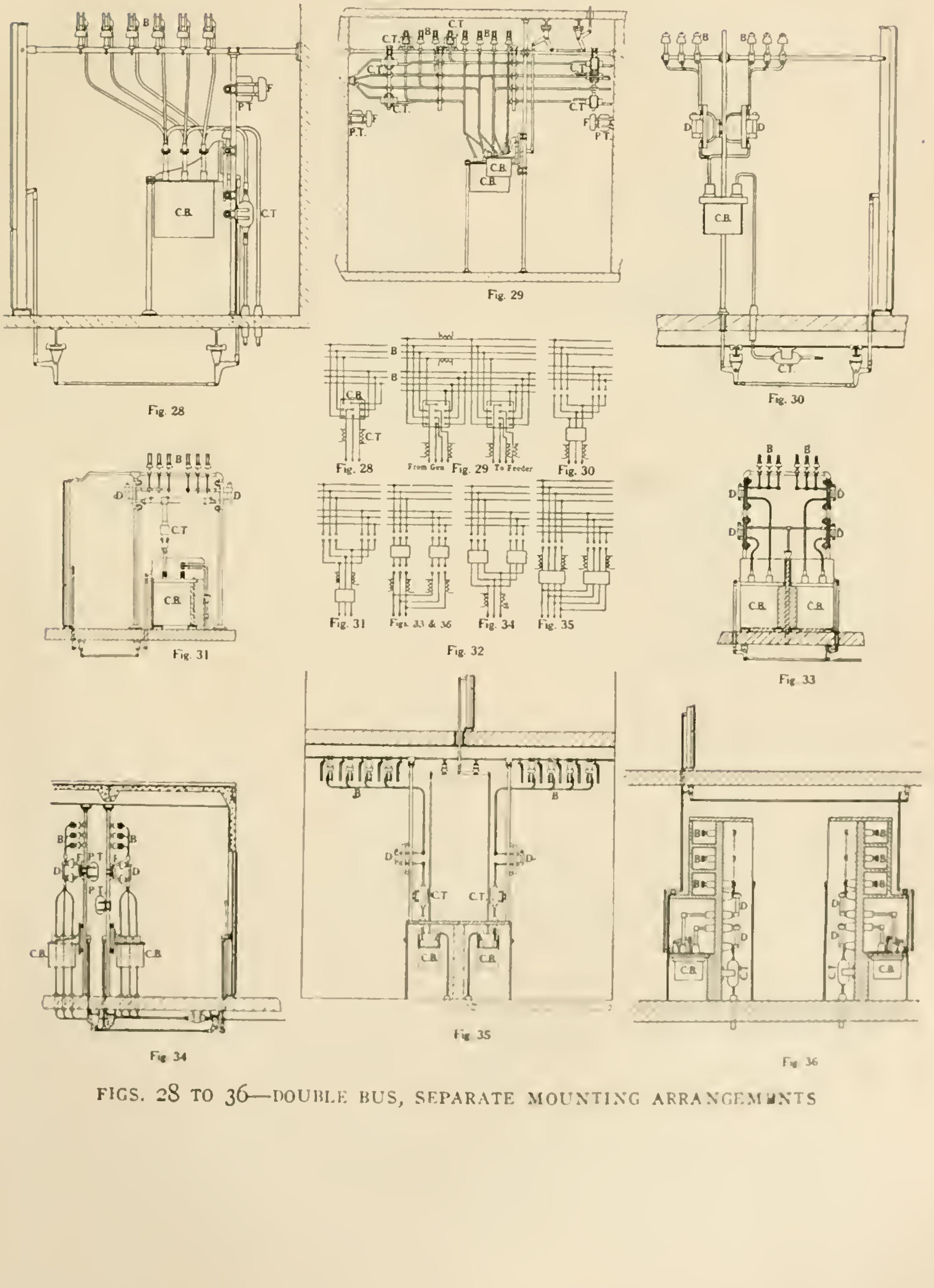


Fig. 28 Fig. 29 Fig. 30 Fig. 31 Fig. 32 Fig. 33 Fig. 34 Fig. 35 Fig. 36

FIGS. 28 TO 36—DOUBLE BUS, SEPARATE MOUNTING ARRANGEMENTS tion, of various panels with complete remote control arrangement based on the panel schedules and arrangements shown in Figs. 1 to 36 inclusive. The panels are 90 inches high with framework of pipe or angle iron, as shown in the corresponding figures. The panel material is black marine finished slate two inches thick, of two sections. All apparatus is of the best grade. The costs include all apparatus scheduled in Table I, and everything shown in the figures which is not a part of the building construction.

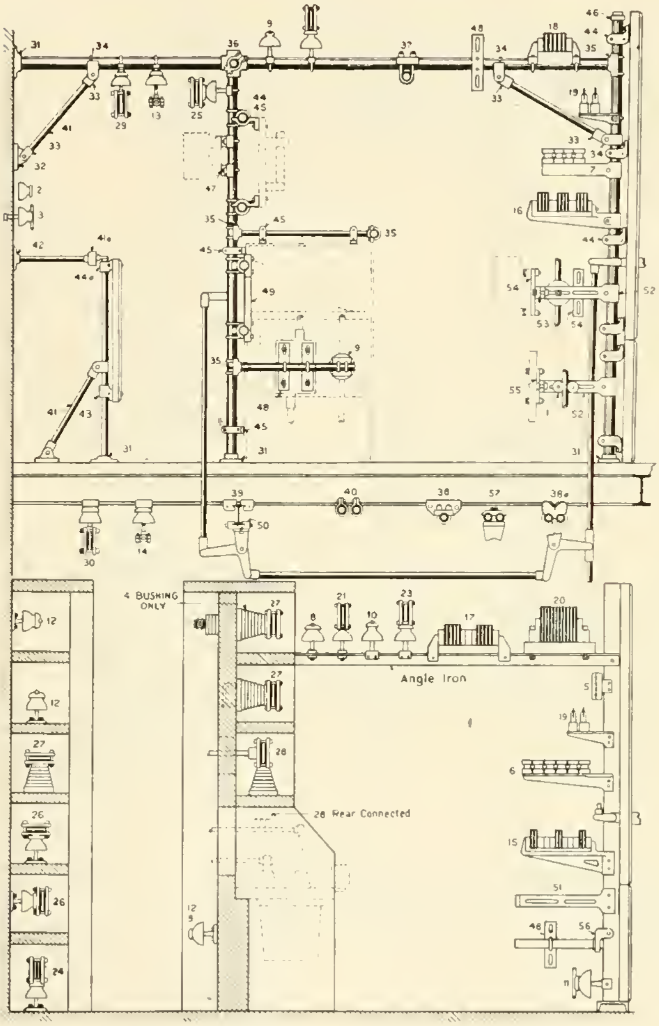


FIG. 38—DETAILS OF SWITCH BOARD CONSTRUCTION FOR PIPE AND ANGLE FRAME WORK AND MASONRY COMPARTMENTS

DETAILS

It is of importance to the appearance of the installation, as well as to its fitness as a unit in the electrical system, that all details of construction, such as supports for bus-bars, electrical connections, operating mechanisms, etc., be uniform in design throughout. Fig. 38 illustrates many of various fittings for both pipe and angle frame, and for both open and enclosed structures, which may be obtained in quantities from any large supply house. In designing a structure the arrangement of parts should be made to conform, as much as possible, to the application of the standard fittings for the obvious reason that the first cost and cost of spare parts will be minimized, and that advantage is thus taken of the experience of others who have aided in the standardizing of such fittings.

THE JOURNAL QUESTION BOX

OUR subscribers are invited to use this department as a means of securing authentic information on electrical and mechanical subjects. The topics should be of general interest and care should be used to include all data necessary for an intelligent answer.

A stamped, self-addressed return envelope should accompany each inquiry. Address all questions to Question Box Department, care THE ELECTRIC JOURNAL, 200 Ninth Street, Pittsburgh, Pa.

895—Relation of Frequency to Eddy Currents—What is the expression for a single law showing the effect of change of frequency upon eddy current loss in a transformer? H. R. S. (PA.)

For any given flux density in the core of a transformer, the eddy current losses will be proportional to the square of the frequency and also to the square of the thickness of the laminations. For any given current in the winding of a transformer, the eddy current losses will be proportional to the square of the frequency.

V. E. A.

896—Cause of High Voltage in Current Transformer—What is the cause for the high voltage produced in the open secondary circuit of a current transformer?

H. R. S. (PA.)

When the secondary of a current transformer is closed through a meter, the ampere-turns of the primary winding are opposed by an almost equal number of ampere-turns in the secondary. When the secondary is open, all of the primary ampere-turns are effective in magnetizing the core and the flux in the core will rise to the point at which the core becomes saturated. There are usually about two hundred turns in the secondary of a current transformer. It is probable that about one volt per turn will be induced in the secondary on open circuit, or there will be about 200 effective volts induced in the secondary on open circuit. Due to the saturation of the iron, this voltage will have a very high peak, possibly two or three times the effective value of the voltage and may therefore prove dangerous. V. F. A.

897—Polyphase Wattmeter Connections—Considering portable polyphase indicating wattmeters, Nos. 1 and 2, Fig. 897 (a), properly connected up, under what circumstances would the potential connections as shown at No. 2 be wrong on account of the secondaries of the potential transformers not having a common connection?

E. J. W. (GEORGIA)

It makes no difference whether such common connection exists or not, as the phase relation will be exactly the same in either case, provided the connections are such that the polarities are correct. In other words, the common connection of the potential coils, as shown at meter No. 1, is merely a convenience, which in some cases effects a saving of wire, but is not at all necessary.

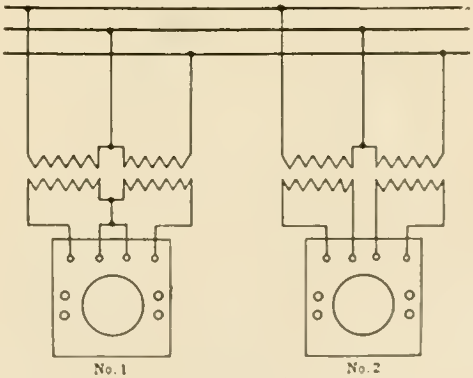


FIG. 897 (a)

C. R. R.

898—Cable Construction Work—There are six triple conductor iron-armored 15 000 volt cables feeding out of a station underground to pot-heads on a steel pole several blocks away, from which three lines run overhead to station A and three lines to station B. It is desired to tap two of these cables in a vault about the middle of the cable, and it is permissible to cut the power off of one line only at a time for testing. How can the two cables wanted be picked out of the six?

R. M. G. (CAL.)

The problem resolves itself into identifying each of the cables in the vault. This can best be done with one cable at a time disconnected, by the interrupter method. For this test a bank of lamps, a device for making and breaking a low voltage circuit, 110 or 220 volts, as most convenient, and a small coil with telephone receiver are needed. The interrupter may be simply a switch which can be opened and closed at frequent and regular intervals by hand, or an automatic make and break, arranged on the shaft of a slow speed motor, or a fan run at reduced voltage. About two breaks a second should be made. For the search coil a core of laminated iron, such as is used in transformers, each piece being about 1 in. by 18 in., should be built up to a height of about one inch, thus making a core 1 in. by 1 in. by 18 in. Around this, wind about 200 turns of No. 20 B. & S. gauge, cotton covered wire, leaving about an inch at each end of core. Bring out the ends of this winding to the telephone receiver.

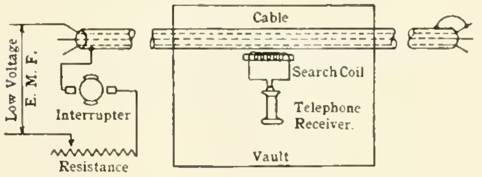


FIG. 898 (a)

Now, disconnect one high tension cable, connect any available low voltage circuit through the lamp bank and interrupter, to one end of the cable, one side of circuit being connected to a cable conductor, the other side to the iron armor of the cable. At the other end of the cable connect the same conductor to the iron armor, as per Fig. 898 (a).

Adjust the lamp bank so that about ten amperes will flow in the circuit, set the interrupter going, and test the cables in the vault with the search coil. Place the search coil alongside of each cable in succession. When the cable to which the interrupter is attached is reached, the regular distinct "click" of the interrupter current will be heard in the telephone receiver. It is possible that a faint click may be heard on the other cables, but the noise will be much louder on the right cable, hence there should be no difficulty in picking it out. As soon as it is found, mark for future identification, and then repeat the process until all cables in the vault are marked.

E. C. S.

899—50 Cycle Rotary on 60 Cycles—Please inform me how to operate a 4 kilowatt, 50 cycle, 4 pole, 58 volt rotary converter on a 60 cycle circuit. (P. R. DE Y. (CUBA)

A 50 cycle rotary can be connected to a 60 cycle circuit and operated in the usual way without any changes. The speed will be 1 800 r.p.m. for a four pole machine, instead of 1 500 r.p.m.

F. D. N.

900—Y-Box—Please explain the wiring connections and operation of a "Y-Box Multiplier," used with a single-phase wattmeter to measure a three-phase balanced load. J. C. H. (ONTARIO)

The device usually designated as a "Y Box" is not a multiplier. It consists of a set of three non-inductive resistors, having one terminal in common and having the other three ends arranged for connecting to the three conductors of a three-phase, three-wire circuit. When so connected, the common terminal becomes the neutral point with reference to the potential of the three conductors. A single-phase wattmeter, connected as shown in Fig. 900 (a) measures one-third of the

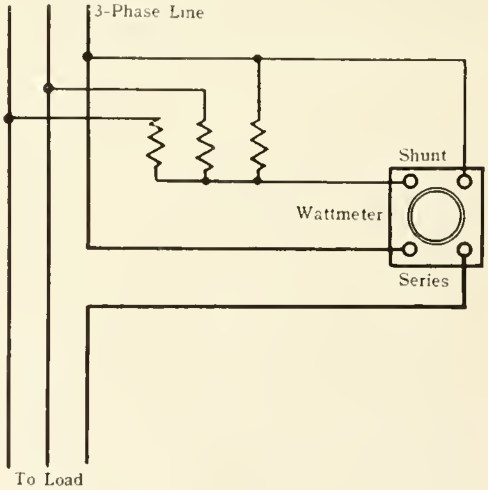


FIG. 900 (a)

total load, if the circuit is balanced. The sum of the readings of three single-phase wattmeters, similarly connected to the three conductors, measures the total load, regardless of balance. When three wattmeters, having exactly equal impedances in their voltage circuits are used, the meter windings themselves form a Y-connection and a separate "Y Box" is not necessary. When the number of meters used is less than three, or when the impedances of the meters are unequal, the resistance of the "Y Box" must be very low, as compared with that of the wattmeter windings to avoid shifting of the neutral due to the current taken by the meter windings. Another method is to use only two extra resistors, each having an impedance exactly equal to that of the wattmeter shunt winding, and dispense with the resistance which is shown connected in multiple with the voltage circuit of meter.

H. B. T.

901—Oil Level in Transformers— How high should the oil be in a self-cooled oil transformer?

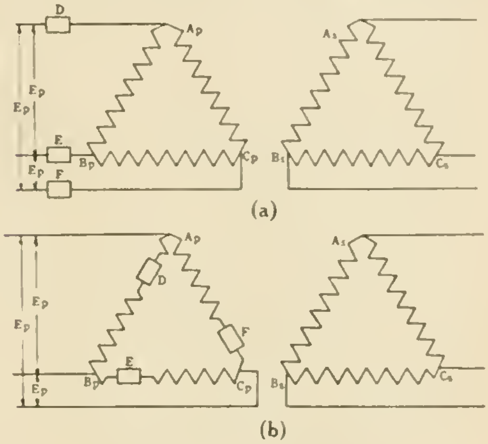
C. R. C. (VA.)

The cold oil level in transformers having cast iron cases should be from one to one and one-half inches below the ledge of the pocket from which the leads issue. In case of sheet metal tanks the cold oil level should be approximately two inches below the top of the sheet metal sides.

902—Transformer Calculations— If one of the primary fuses are blown in a bank of delta connected transformers, what is the rule for calculating the secondary voltage in all three phases?

C. R. C. (VA.)

To determine the secondary voltage, if primary fuses are blown on delta connected transformers, take first the case of fuses directly in the line, Fig. 902 (a). If fuse D blows, a single-phase e.m.f. is applied across B_p C_p. Now as transformers AB and AC are exactly alike, they will divide this e.m.f. equally, provided there is no unbalanced secondary load. Then we will have full voltage on the secondary B_s C_s and one-half voltage on A_s C_s and A_s B_s. If load is taken from A_s C_s, the voltage across this phase will fall and the voltage across A_s B_s will rise. In the case in which the primary fuses are connected directly in the transformer primary circuits, as in Fig. 902 (b), if fuse D blows, there is a condition of A_p C_p and B_p C_p acting as two transformers connected in V and transformer A_p B_p plays no part in the action except to draw exciting current through its secondary. Three-phase current may now be drawn from the secondary, though the capacity is of course reduced. The voltages on the secondary are still full value three-phase, but on unbalanced load do not operate as satisfactorily.



(a)

(b)

FIG. 902 (a) AND (b)

903—Difficulty in Paralleling Alternators— I have two generators in a power plant, each driven by a triple expansion high speed engine, the output of each being 500 kw at 80 percent power factor, three-phase, 60 cycles, 6600 volts, at 300 r.p.m. Both these machines when running individually give the best of satisfaction, the governing giving three percent permanent and five percent momentary variation, from no load to full load, whilst the generators have about the average regulation. Both generators are of the same make, but I find it quite impossible to get them to stay in parallel. They throw in alright, but the incoming machine always refuses to pick up load even if running slightly fast and with a little excess voltage. If we raise the speed or voltage a little more, it begins to pick up load.

but the governors of the engines start to hunt and the two machines fall out of step usually after a lapse of two to seven minutes. I would mention that the hunting always seems to start on the one machine which was the last to be installed. The air-gap on this machine is at least 1/16 smaller than on the old one. This is due to the fact that the rotor field coils were damaged by sea water during shipment and were rebuilt by the maker's agents. These poles are bare copper strap wound on edge and insulated with presspahn discs. I find that some of the pole pieces are considerably deeper than others, i.e., some give 3/16 air-gap whereas others only give about 3/32. Would this cause any alteration in wave form sufficient to affect parallel running? Would it be advisable to machine the pole faces so that each would give an air-gap approximating that of the other machine? What steps would you advise me to take?

H. S. G. (CANADA)

This difficulty in parallel operation is probably due to the hunting of governors combined with the low percentage speed variation between no load and full load of the individual engines. It is not probable that the differences in air-gap have anything to do with the matter. It would not be advisable to do any work to correct the air-gap until the difficulties with the governors have been eliminated. In general, the changes in governors required should be such as to increase the percentage regulation of individual engines and to add dashpots to the governors to prevent oscillation and hunting. It is also possible that the flywheels are too light for proper parallel operation. It is not probable that the local engineer can remedy these defects unless he has had considerable experience with similar troubles. The engine builders should be appealed to for assistance.

F. D. N.

904—Resistance of Cast and Rolled Copper—What is the difference in resistance between a cast copper bar and a rolled copper bar of the same dimensions?

W. S. D. (PENNA.)

The resistance of copper varies greatly, depending upon its purity. Rolled or drawn copper may be expected to have a resistance of 0.158 to 0.1596 ohms at 20 degrees C. per gram-metre, and cast copper a resistance of 0.1915 to 0.221 ohms at 20 degrees C. per gram-metre.

R. W. E. M.

905—Connections for Starting Boxes—We notice that some manufacturers place the low voltage release coil of their starting boxes for direct-current motors directly across the line instead of as in the ordinary three-point starting box. Another manufacturer places this coil in series with the shunt field. Why is the former method used and in what way does it take care of open circuits in the shunt field, providing no overload release is on the starting rheostat?

F. D. P. (OHIO.)

A large number of present day motors are designed for adjustable speed by shunt field control. The range of shunt field current is so great that it is practically impossible to design a no-voltage release coil to go in series with the shunt field and work over this range. A coil in series with the field must be designed with reference to the particular motor with which it is to be used, as the shunt field current varies in differently designed motors of the same horse-power rating. In order to avoid these difficulties the coil is put across the line. It does not afford any protection against open circuit in shunt field, this contingency being taken care of by the overload circuit breaker or fuses in the line.

H. C. N.

906—Shunted Interpole on Generator—On a 500 kw, 500 volt railway generator, two resistors in series are connected in parallel with the interpole winding. One of these is a straight resistance similar to the shunt on the series field, while the other is a reactance coil. Please explain the action and give reasons for the use of either or both.

C. A. F. (KANSAS.)

Under certain conditions it is impracticable to design the commutating pole windings for an exact number of turns and still maintain the correct proportion between armature and commutating pole magneto-motive forces. In such instances a winding slightly heavier than necessary is supplied and the excess current shunted off. Both inductive and non-inductive shunts have been employed for this purpose. The latter type, however, is unsuited for operation on circuits of varying load as they by-pass more than their proper proportion of current during sudden fluctuations. For good commutation practically a fixed ratio between commutating pole and armature strengths is advisable below saturation of the commutating pole magnetic circuit, and to secure this a fixed division of current between the commutating pole windings and its shunt circuit is required. The insertion of inductance in the shunt circuit tends to equalize the inductive action of these two parallel circuits and extended oscillograph tests have indicated the most suitable proportions to be used. R. H. T.

907—Battery Power Gathering Locomotive—We have a small gathering locomotive equipped with a 10 or 12 horse-power, 110 volt, series motor, also an Edison storage battery of 60 cells of 150 ampere hours capacity. The voltage of the trolley wire in the mine is 250 volts. Would it be practical to connect the controller starting resistance motor and battery so that while the motor was running from the trolley the battery would be charging and when the end of the trolley was reached the motor would run from the battery, assuming that the motor was run 40 percent of the time on the trolley wire and 60 percent on the battery and the battery would be charged at the beginning of each 10-hour shift? E. C. (W. VA.)

The discharge voltage of 60 Edison cells is between 60 and 72 volts, while the voltage at the motor when taking current through the battery from a 250 volt trolley would be 125-145 volts. For this reason the starting resistance for operation from the battery would be much less than that required for operating in series with the battery from the trolley. To determine the correct amount of resistance for use in each case, the locomotive weight, characteristics of motor, gear ratio and wheel diameter should be known. The speed when operating from the trolley will be approximately double that obtained with the battery alone; and the maker of the motor should be requested to state whether the motor will stand a maximum voltage of 150 volts at light loads. To know whether such intermediate charging would be sufficient to keep the locomotive in service for ten hours, it would be necessary to have more definite information as to service conditions; namely, loads, distances, frequency of trips, running time, etc. Under average conditions we estimate that 10 or 12 hours service could be obtained in this manner before the battery is completely discharged. E. W.

908 — Horse-power Formula — Is the following formula practical for finding the horse-power of three-phase, 25 cycle, 400 volt motors:—

$$\text{Hp} = \frac{1.732 \times \text{E} \times \text{I} \times \text{PF.}}{746}$$

Where the power-factor is not known would you advise using a portable power-factor meter? If not give practical method. Also give formula for finding proper size of wire for wiring three-phase, 25 cycle, 400 volt motors. A. E. J. (PENNA.)

The formula is correct for determining the electrical horse-power input to the motor. To determine the mechanical load connected to the motor, the horse-power input must be multiplied by the horse-power efficiency at that load, which can be obtained from the efficiency curve for the particular motor. The formula given requires simultaneous measurements of amperes, volts and power-factor. A more practical way is to measure the input by using wattmeters and dividing by 746 to get the horse-power input. The size of wire is determined by the size of current it must carry. This current can be determined from the name plate, by direct measurement or by the formula $\text{I} = \frac{\text{Hp output} \times 746}{1.732 \times \text{E} \times \text{P. F.} \times \text{Eff.}}$ The size of wire for a given current may be obtained from tables supplied by wire manufacturers or Underwriters or from tables in electrical handbooks. C. W. K.

909—Changing Motor From Two-Phase to Three-Phase—In several repair shops I have noticed the practice of changing the coil and group connections of induction motor stator windings, so that they can be used on either two or three-phase circuits, as circumstances may require. Coil positions in the slots are not changed, merely the dividing up of coils into two or three circuits. Now it is obvious that this changes the voltage per coil, also the coils do not lie in the proper polar positions, hence I have concluded that a three-phase motor changed to two-phase would have reduced output. Let me know the facts and performance of motors so connected and whether such changes are considered good practice or not. I would suppose a Scott connection of coils (leaving out one or more coils per pole to get the required 86 percent) would be preferable. S. P. (WASH.

Assume a three-phase, 440 volt motor having 36 coils conected in series star. As a three-phase motor, it has one-third of 36 or 12 coils per phase on 254 volts or 21.2 volts per coil. When reconnected for two-phase, one-half of the coils or 18 are in one phase on 440 volts or 24.4 volts per coil. Also on account of different distribution of the coils, the voltage per coil on two-phase is increased six percent above the three-phase, making the voltage per coil 25.8 volts on two-phase. Thus the voltage per coil is 22.5 percent greater on two-phase than on three-phase, making the pull-out point of the motor about 50 percent greater on two-phase and increasing the saturation of the iron. The motor when connected for two-phase will have greater no-load current and lower power-factor and efficiency. The converse of the above is also true. In general, it is not good practice to increase or decrease the voltage of a coil more than ten percent. In changing from two-phase to three-phase the Scott connection would give a motor more nearly like the original than the above. This connection is not always possible as the coils omitted should be evenly distributed among all the poles and this may be impractical.

C. W. K.

910—Efficiency of Enclosed Motor—a—Is there any way to figure how much an enclosure put on an open type motor lowers the efficiency of the motor? b—Is there any liability of causing faulty operation of a semi-enclosed motor by protecting the ventilating openings with a wire gauze screening to prevent sparking hazards?

K. W. A. (MO.)

a—In general, a motor rated at 40 degrees C. temperature rise for continuous service can be equipped with semi-enclosing covers of grid or large wire mesh type and operated at the same horse-power with temperature rise not exceeding 50 degrees C. The efficiency is affected to the extent of increased copper losses due to greater resistance of copper on higher temperature. This affects armature, commutating pole and series circuits. In general, an armature with a given continuous horse-power and speed rating at 40 degress C. rise for unenclosed operation will, if totally enclosed, have a continuous rating at 55 degrees C. rise of aproximately 70 percent of the previous horse-power rating at a speed increased approximately 20 to 25 percent. b—If wire mesh is not under one-quarter inch, there is not much danger of overheating provided the motor runs within 50 degrees C. rise with sandard grid enclosing covers. A motor operating within the standard 40 degrees C. rise unenclosed, should do this.

A. C. L.

PERSONALS

Mr. Arthur J. Sweet, commercial engineer of the Holophane Works of the General Electric Company, has resigned to enter consulting engineering work at Milwaukee, in connection with Francis A. Vaughn and H. J. Meyer, under the firm name of Vaughn, Meyer & Sweet. During the past five years Mr. Sweet has been prominently identified with research and commercial development work in the field of illuminating engineering. He was engaged on shop process work in the research engineering department of the Westinghouse Electric & Mfg. Company, and later was electrical engineer for the Westinghouse Lamp Company. During the past two years he has given special attention to the subject of railway lighting, and last summer served as consulting engineer in charge of the research work on postal car lighting which was conducted at Washington, D. C., under the auspices of the Baltimore & Ohio Railroad. Mr. Sweet has been a valuable contributor to the Journal and other technical periodicals, as well as to the engineering societies. He will give his chief attention to the handling of the firm's extensive illuminating engineering practice and to directing the details of the office work. Mr. Sweet's energy and conscientiousness in his work have won him many friends whose good-will and support will follow him in his new work.

Mr. Arthur J. Sweet

Mr. Arthur Warden, of the railway and lighting sales department of the Westinghouse Electric & Mfg. Company, has accepted a position in the office of the master mechanic of the Washington Railway & Electric Company at Washington, D. C.

Mr. H. N. Bartlett, for many years in the engineering department of the Westinghouse Electric & Mfg. Company, East Pittsburgh, is now located at the Pittsfield works of the General Electric Company, in the engineering department.

Mr. W. S. Murray, chief electrical engineer of the New York, New Haven & Hartford Railroad, has resigned, to enter consulting engineer work in partnership with Mr. E. H. McHenry, until recently vice-president of the same road. The new firm, with offices in the Second National Bank building, New Haven, will take over a large part of the electrical engineering staff of the New Haven Railroad and will direct the new electrification work of that company as consulting and constructing engineers. The firm will be prepared to undertake other railway engineering work, and already has been in consultation on several important western electrification projects. The long experience of both members of the firm, during which they have supervised electrification of 550 miles of track, involving the expenditure of more than $15 000-000, well fits them for the field of work in which they will engage.

Mr. John Hays Smith, commercial engineer of the Milwaukee Electric Railway & Light Company, in charge of engineering and sales of electric power and steam heat, has resigned to engage in consulting engineering, with offices in the Merrill building, Milwaukee. Before coming to Milwaukee Mr. Smith was with the Duquesne Light Company of Pittsburgh, and previously with the Westinghouse Electric & Mfg. Company, for seven years. Since going to Milwaukee, Mr. Smith has closed some of the biggest electric power jobs in that city, and introduced the first electric steel furnace to be installed in the Northwest.

Mr. L. de Verebely, who took the engineering apprenticeship course of the Westinghouse Electric & Mfg. Company in 1907 and 1908, later was in their power engineering department, and has since been connected with the Ganz Electric Company, Budapest, Hungary, in their experimental department, has been appointed chief engineer of the Italian Westinghouse Company, Vado Ligure, near Genoa, Italy.

Mr. Harold W. Smith, formerly of Pittsburgh and later of the Milwaukee office of the Westinghouse Electric & Mfg. Company, has been appointed sales engineer to Noyes Brothers in charge of electrical estimates, and selling, with headquarters at 115 Clarence street, Sydney, Australia.

NATIONAL ELECTRIC LIGHT ASSOCIATION—PRELIMINARY PROGRAM

The annual convention of the National Electric Light Association will be held June 2-6, at Medina Temple, Chicago. On Monday, June 2, the exhibits will be opened and in the evening will be the reception of President Tait. From Tuesday until Friday there will be two sessions daily, with often two or three sections in parallel.

A list of the proposed special papers is as follows:

Paul Lupke, "Anticipation"; W. A. Thomas, "Central-Station Power in Coal Mines"; Paul MacGahan, "Switchboard Instruments"; E. P. Dillon, "Railway Loads for Central Stations"; H. H. Rudd, "Transformers and Power Transmissions"; W. A. Darrah, "Arc Lamps and Recent Developments Thereof"; J. N. Mahoney, "Developments in Protective Apparatus"; E. G. Reed, "Latest Developments in Distributing Transformers"; R. E. Campbell and W. C. Cooper, "The Incandescent Lamp and Its Relation to Lighting Service"; J. E. Randall, "New Incandescent Lamp Development"; August Hibbard, "Use of the Telephone in Central Stations"; R. A. Griffin, "Poles and Pole Preservation"; E. B. Merriam, "Switching Apparatus for Rural Installations"; J. Edward Kearns, "Central Stations for Towns of 5 000 Population or Less"; T. K. Stevenson, "Advantages of Copper-Clad Wire for Series Arc Lighting."

The following items and names give a list of regular reports and addresses, embracing, with the subsequent lists of papers, between 60 and 70 separate items proposed to be taken up and disposed of by the Convention, although, of course, some changes may be made before the program goes into effect:

Frank M. Tait, President's Address; T. C. Martin, Secretary's Report and Progress Report; W. W. Freeman, Treasurer; Wm. H. Blood, Jr., Insurance Expert; Arthur Williams, Public Policy Committee and Library; Frank W. Frueauff, Constitution and By-Laws; E. W. Lloyd, Rate Research Committee; Holton H. Scott, Membership Committee; S. A. Sewell, Question Box Editor; E. J. Bowers, Accounting Committee; I. E. Moultrop, Prime Movers Committee; Frank W. Smith, Lamps; W. H. Fellows, Meters; W. H. Blood, Jr., Grounding of Secondaries; Dr. A. E. Kennelly, Electrical Measurements and Values; Farley Osgood, Overhead Line Construction; L. L. Elden, Electrical Apparatus; W. H. Gardiner, Terminology; W. L. Abbott, Underground Construction; John W. Lieb, Street Lighting; T. C. Martin, Memorials.

COMMERCIAL SECTION

The work of the Commercial Section will include an address by its chairman, Mr. E. W. Lloyd, and a special address on the education and training of salesmen, as well as the following reports of committees:

Finance—T. I. Jones. Publication—Douglass Burnett. Membership—J. F. Becker. Electrical Salesman's Handbook—E. L. Callahan. Electricity on the Farm—John C. Parker. Wiring of Existing Buildings—R. S. Hale. Ice and Refrigeration—G. H. Jones. Electrical Merchandising—T. I. Jones. Short Cuts in Executing Customers' Orders—G. C. Holberton. Steam Heating—S. M. Bushnell. Advertising—J. R. Crouse. Education of Salesmen—George Williams.

HYDRO-ELECTRIC AND POWER TRANSMISSION SECTION.

The work of this Section will include an address by the chairman, Mr. W. N. Ryerson, and a special discussion before the Section by an engineer from the Bureau of Standards of the subject of life hazard in connection with the transmission and distribution of power. The Committee reports to be taken up are as follows:

M. R. Bump, Receiving Apparatus; P. M. Downing, Distributing Lines; D. B. Rushmore, Operation of Water-Power Systems; R. J. McClelland, Membership; T. C. Martin, Power Transmission Progress.

It is also proposed to discuss in this Section the part of the report of the Committee on Prime Movers, relating to a special investigation of water-power plants and apparatus made by a sub-committee, with Mr. J. F. Vaughan as chairman. The following papers have also been prepared:

A. O. Austin, Factors Producing Reliability in the Suspension Insulator; R. D. Coombs, Transmission Lines; H. L. Cooper, The Mississippi River Power Company's System (illustrated); E. E. F. Creighton, Lightning Arresters; Albert Kingsbury, The New Type of Thrust Bearing.

It will be seen that the Section has an unusually interesting program. Some attention will be given to Conservation but the specifically political aspects of this will be reserved for the report of the Committee on Public Policy.

THE
ELECTRIC JOURNAL

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Central Station Progress

Ten years ago central station managers were content to devote their energies almost exclusively to the expanding of their electrical illumination business, unmindful of the fact that the requirements of their customers necessitated twenty-four hour operation for a revenue load condensed in an evening peak of not more than three or four hours. Since then, central station managers have been wonderfully aggressive and progressive. They have sought a day load to fill their power valleys and have striven incessantly for power business with the result that today in many cases the current consumption due to domestic illumination is but a by-product of the central station's activity. Splendid strides have been taken in this direction during the past year, and central station managers are attacking the future with the hope and belief that within a very few years central stations will supply practically all of the industrial power consumed, will supplant to a large extent coal and natural gas for domestic heating and will make even more surprisingly large inroads upon the less modern forms of illumination still so widely used.

This remarkable progress has been largely due to hearty coöperation between the electrical manufacturers and the central stations. The manufacturers have been progressive and active in developing new types of apparatus designed to increase power house efficiency and reduce the cost of production. The advance in this direction has been almost revolutionary. In fact, inventive skill, chastened by healthy competition, has been kept so active in the development of electrical apparatus that central station managers have been spurred to increased efficiency on their part to assimilate economically the ever-changing, ever-improving types of electrical machinery. Increased economy resulting from larger and better power house units and a more efficient system of current distribution have been generously shared by central station managers with the result that new business has been created at prices that might cause old-time electrical men some moments of anguish.

Central station managers have combined high efficiency of production with keen commercial activity. They have waged a persistent campaign of education to popularize the use of electricity. They have improved the standard of their product. They have preached the gospel of reliable electrical service—service that means one hundred percent efficiency every moment the clock ticks. They have shown industrial managers their error in maintaining grossly extravagant and wasteful methods of individual power production, simply because their fathers had been successful with such methods. They have called in the technical expert as a vital part of their operating forces and they have systematized on a basis of science and precision a business that formerly was notoriously haphazard. They have developed the small power business as well as the large, and have convinced the manufacturer that central station power service is so elastic, so cheap, so clean, so safe, so efficient and so reliable that it is indispensable for economic manufacturing.

Each year new lines of work are found where electricity may be advantageously applied, aside from the production of light and power. The manufacture of high grade steel in large quantities through its use is but in its infancy, and among some of the other important lines are the manufacture of tungsten, aluminum, silicon, artificial graphite, calcium carbide for the production of acetylene gas, nitric acid from atmospheric nitrogen, artificial fertilizer in which nitrogen obtained from the atmosphere plays an important part, etc. The future of the industry seems boundless and the central station manager is alive to the opportunity.

R. S. Orr

The Eye a Factor in Illumination

The eye and the hand have a large part in nearly everything we do. The eye sees what should be done and the hand does it; the eye directs the movements of the hand; it observes whether the proper result is attained. This is strikingly true in industrial work. The supervision by the eye applies alike to the clerk, the draftsman, the carpenter, the moulder, the machinist, the watchmaker, and those who test and inspect the finished product. It is primarily the eye which determines what should be done, which directs the doing of it and decides whether it is properly done.

The eye is the most sensitive and delicate of the organs of sense. It should be aided and protected in every way practicable. The object to be seen should be properly illuminated, and the eye should be protected from irritation and strain. At a lecture and in conversation we insist on quiet surroundings so that the ear may be free from disturbing noises or shrill whistles. But we are careless about the eye. It is often subjected to glaring light from surrounding objects or from an intense lamp or from polished surfaces on the object it views. To protect itself from glare and penetrating light, the pupil of the eye contracts; but this is not the best condition for seeing the work in hand. The eye has a wide range of accommodation to different degrees of illumination, but it is subject to temporary or permanent injury if the strain upon it be too great or too long continued.

Eye strain produces impaired vision, headache, bad disposition and a general unfitness for efficient service. In some industries, advancing years bring experience and skill of hand, but a failing eye sight. The oculist may prescribe a partial remedy, but prevention by the illuminating engineer may greatly reduce the need of attentions by an oculist. In short, the efficiency of the eye and of the individual and the resulting quantity and quality of the work accomplished are very largely dependent upon normal vision and proper lighting; it is this which makes illumination of fundamental importance in industrial economy. There are safety devices to protect the hand from injury by moving machinery; vision must be conserved by protecting the eye from dangerous lamps.

What constitutes good lighting? The question admits of no simple answer, though one usually tries to name some kind of a lamp. But the problem logically begins not with the lamp but with the eye itself. The problem is physiological, it is even psychological, for the real object of illumination and of seeing is that the mind may receive certain impressions through the physiological stimulus caused by the light from the observed object. The outward facts should be made known to the mind accurately and with minimum strain upon the delicate mechanism of the eye. The problem, therefore, is to make the outward physical conditions of lighting conform to the needs of the eye. In the physical problem, the illumination of the object itself is only one factor, as the surrounding conditions and the prevention of glare are of equal or even greater importance.

The illumination should differ with different objects. Some things seen are large and others small; some are light in color and others dark; in some, color values are important; some require close observation of delicate parts or of a particular point, while others require a general view of a large area. The surroundings differ widely; sometimes there are light walls and ceilings, and in other cases there are, from the standpoint of illumination, neither walls nor ceilings; sometimes the lamps may be placed wherever desired, and in other cases their location is limited, as by cranes or otherwise.

Until recently illumination has received very little attention. A dozen years ago, gas jets, sixteen candle-power incandescent lamps and arc lamps were practically the only sources of light. There was little appreciation of the importance of illumination either by scientific men, by engineers or by factory managers. In the last dozen years there has been progress all along the line from the coal pile to the retina. Attention was first given to the production of current; larger power plants, with improved economy in boilers, turbines and other appliances made it possible for one ton of coal to do what used to require an average of two tons; present day lamps consume only a half or a third as many watts per candle-power as their predecessors; then reflectors have been produced which redirect the light and double the useful portion on the working plane. The problem has shifted from the mere getting of the requisite light on the object to the more difficult problem of not getting too much light where it is not wanted. We are now passing from the lighting to the seeing, from physical light to impressions on the retina.

The relation of the eye to illumination is being studied by a committee of the American Medical Association dealing with the conservation of vision. Investigations are being made of methods for determining the visual acuity and the effect of eye strain under different conditions of illumination. All this means that there is opening up a large field with many problems where it was scarcely recognized that there was any problem at all. The new illumination has been forced forward by the advent of the tungsten lamp, which, properly applied, brings results in the economical production of light in convenient form heretofore impossible. On the other hand, improperly used it is a menace and a danger. The installation and maintenance of bare tungsten lamps in the line of vision should be made a criminal offense.

The eye, the director and monitor of industrial effort, deserves the best illumination obtainable. The difference between good lighting and poor lighting in immediate returns of output and quality are difficult to determine. It has often been estimated at from two to ten percent; this means that from twelve minutes to an hour is gained each day of ten hours, if the light is good. There is less delay, there are fewer mistakes; the more cheerful surroundings animate and enliven. On the other hand, the increased cost of good lighting as compared with poor lighting in many cases does not exceed more than a fraction of one percent of the cost of production. Even an individual lamp at a tool chest which enables a man to save two minutes a day in hunting for things will save a whole day's time in a year.

The problem of good lighting, therefore, is not simply a question of power, or what lamp to use, or what reflector is the cheapest, or the most efficient, but it is a question as to what illumination enables the eye to perform its function with the highest efficiency and with the least strain. The lighting which best promotes and preserves vision, which produces the least strain upon the eye and nerves, is cheap at any cost. We have improved the cost per kilowatt-hour and the watts per candle and now we are trying to conserve our eyesight. We pay for kilowatt-hours, we buy illumination, we want good vision. The last is first in importance.

CHAS. F. SCOTT

The Year's Advance in Illumination

The past year has been notable for a number of valuable developments in the incandescent lamp field. A further increase in the efficiency of tungsten lamps of twenty percent has been secured, which brings the expense for lighting down to a very reasonable figure indeed, it being now possible to obtain equivalent illumination at from one-fourth to one-third the expense required when using the old carbon filament lamps. Another favorable feature from the consumer's standpoint is the decreased price of tungsten lamps.

The more recent developments have been in the nature of refinements in quality and methods of manufacture rather than any radical changes necessitating spectacular modifications in methods of illumination. There has been a decided increase in the application of established principles of illumination and in the introduction of good lighting into locations which have heretofore been considered as beyond the reach of available methods.

While the need of good lighting in industrial establishments has been self-evident, insufficient attention has been given to the means of securing artificial light, especially in locations where it is needed only a few hours per day. It was through the efforts of both the engineering and medical societies that the matter of proper illumination was brought to the attention of the public. Legislation was finally enacted, rather indefinitely specifying that workrooms should be properly lighted. Recently a further step was taken, and legislation is pending both in this country and abroad indicating the minimum intensities for different locations, as well as other means for safe-guarding the eye sight and comfort of employees.

The year has witnessed the standardization of the "Light Centre", that is, all manufacturers of incandescent lamps have standardized the distance from the base of the lamp to the point at which the filament may be considered as concentrated. This is of great benefit, as the distribution of light from reflectors will thus be that for which they were designed, regardless of the make of lamp used. It also simplifies the work of the reflector and fixture manufacturer by giving definite measurements on which to base calculations.

The methods recently developed for the prevention of blackening, as mentioned by Mr. B. F. Fisher, Jr., in this issue, mark a decided step in tungsten lamp progress, both by allowing the operation of lamps at still higher efficiencies than heretofore, and by bringing the burn-out and blackening points more nearly together. The ruggedness of tungsten lamps as now manufactured seems little short of marvelous to those who had experience with the first commercial tungsten lamps. Their regular use five in series on 550 volt street railway cars indicates that they are now sufficiently rugged for all ordinary requirements.

By the introduction of the low wattage tungsten lamp of the 110 volt type, a means for decorative lighting with low intensity at small current consumption is provided. Thus the gap between the low voltage and the normal voltage lamps has been successfully filled.

The reduction in the size of bulb of the 40 and 60 watt lamps is of great benefit in certain types of lighting. The 40 watt tungsten lamp can now be substituted for the ordinary carbon filament lamp without any change in the fixture. The 60 watt lamps are now of the same size as the older 40 watt lamps. These reductions in size of bulb increase the extent to which these lamps can be applied to artistic lighting and, by approximating the size of the carbon lamp, make changes to higher candle-power possible at slight expense.

Possibly the greatest advantage of the increased efficiency and lower first cost of tungsten lamps, is the removal of the necessity for extreme economy. Now that an abundance of light can be had at slight cost, and in units to suit a great variety of conditions, more attention can be given to securing pleasing results by the use of auxiliaries for softening and directing the light. Heretofore, regardless of the benefits to be derived, it has unfortunately been the case that the application of good lighting principles has been very largely limited by the first cost of installation and operation. We can now afford to sacrifice something in efficiency for artistic effect. This is especially true of residences and places for public or semi-public use.

E. R. TREVERTON

Getting a Perspective on the Central Station Industry

The use of central station energy as a source of power for manufacturing purposes is a comparatively recent development. Twenty years ago, illumination was regarded as the principal function of the "lighting company". Since that time, the growth of the central station industrial power load has been exceedingly rapid—in fact, there are few if any industries which have had such a rapid growth.

In the present issue of the JOURNAL, Mr. A. E. Rickards gives some interesting data, based on the latest United States Census returns. These figures as presented are used as the basis for an argument in favor of central station service but, aside from their value for this purpose, they form food for thought which should cause all those interested in power generation and utilization to look well into Mr. Rickards forecast, as it indicates an enormous expansion in the power business before the next census is taken.

Ten years ago, according to his figures, seven and one-half percent of the power used in manufacturing was electrical. In 1910 this figure was twenty-seven, an increase of 360 percent. At present, six and three-fourths million horse-power is being furnished electrically, and it is estimated that by 1920 manufacturing establishments requiring over twenty million horse-power will be operated by motor drive. This is over three times the amount of power being supplied electrically at present and is nearly as much as the total power now in use for manufacturing. At first glance such an enormous increase in less than eight years may seem somewhat visionary; but the curves shown indicate that the method of forecasting is fairly conservative.

The figures discussed include only the power used in manufacturing and do not take into account the growing present tendency for central stations to take over large railway loads, which should result in organizations still better able to supply satisfactory power service to large manufacturing concerns. In addition, there is the gradual knitting together of many separate plants which has now begun and which will probably continue at an increasing rate, until large districts are supplied with electrical energy from one interconnected network of power lines.

The electric motor, without which this remarkable growth could not have taken place, has itself been greatly improved within the last ten years. It is now a very sturdy piece of apparatus, light of weight and easy to install. Designs are continually being developed leading to an increasingly large number of operations to which the motor can be applied.

The engineering features necessary to such a large increase in power supply appear to be largely solved. The ability of central stations to furnish continuously a uniform quality of power, and the economics of power application will undoubtly largely affect the expansion of electric power utilization in the next few years. Some systematic and fairly uniform method of charging for power is also needed. The demand has increased so rapidly that there is still some uncertainty as to the proper basis of charging for power service of various kinds.

The public service idea, with a fair and open policy to the community served, as well as the necessary desideratum of good service, will undoubtedly feature largely in future expansions, and should prove an excellent means of helping to keep the national power load curve on the predicted upward path.

A. H. McIntire

ILLUMINATION OF BUSINESS STREETS

G. W. ROOSA

THAT improved street lighting, characterized by predominance of ornamentation and increased illumination intensity, pays in dollars and cents when used in business sections has been considered axiomatic by manufacturer, engineer and user. As a result very few figures have been presented on the subject. In a previous article* the author gave a prominent position to the advertising value of improved lighting for streets lying within the business section of a city. A detailed investigation of ornamental street lighting conditions extending through twenty-four states brings out some interesting facts.

ADVERTISING VALUE OF "WHITE WAYS"

To arrive at the desired conclusions a study must be made of the relation of the advertising value of illumination to its cost. Notwithstanding the fact that the value of the modern ornamental business street installation is composed of several other important factors, such as the aesthetic and architectural improvements involved, the attraction of people to the town or streets so lighted, the decrease of accidents in spite of increased traffic and the spectacular effect produced at night, the desired figures will be most closely approximated by a consideration only of advertising value to the average merchant, as represented by the effect upon his business. It goes without saying that the location of the street, the size of the city and the characteristics of the merchants or concerns doing business on that street will modify the results.

The average annual cost per foot frontage to the merchant, as indicated by our modern "white way" systems, is ninety cents. This means forty-five dollars a year to the man with a building having a fifty foot front. The replaced system of lighting maintained through the taxes or directly by the merchants or owners under average conditions may have cost anywhere from ten to forty cents per front foot, depending upon the system and the local conditions. Assuming an average of twenty-five cents, gives an increase in cost per foot front per annum of sixty-five cents. This means thirty-two dollars and fifty cents actual cost to the merchant having a fifty foot frontage. Assuming then, that his business is such that the actual profits are ten percent of the total annual business, the improvement will pay him in dollars and cents when it increases his annual business by an amount greater than three hundred and twenty-five dollars.

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*"Aesthetics in Street Lighting," in the JOURNAL for February, 1913

The effect of the "white way" is perhaps more readily seen in some classes of business than in others. The amusement theatres and the cigar stores realize immediately the advertising value of the new system. These are of the class that remain open six or seven nights a week. Usually they deal in small commodities. Another class includes the department stores, the clothiers and the markets who are open but one or two nights a week. As they deal in larger commodities they receive a proper portion of the benefits. A third class, which includes the banker, the builder, and such concerns as seldom do business after sunset, profits indirectly by the impulse given the other local business activities.

At the present time extended inquiries on this subject are being made from which, although the investigation is not completed. the indications are that all classes of business should, under ordinary conditions, find "white way" lighting a paying investment. The cafè, the amusement theatre, the drug and confection store, the barber shop and the tobacco store do a large business during the hours of artificial illumination. Although their commodities are small they appeal to the strolling class of people brought to the street by the brighter illumination. Jewelers, clothiers, florists, dentists, department or furniture stores, open but one or two evenings a week, catch the people who are busy during the working hours and have only the evenings in which to shop. Further, their business is increased somewhat in the hours of daylight by the increase of habitual traffic. Two forces of habit act to build up business on the street; first, the public acquires unconsciously the habit of using it by night and day, soon giving it preference over other routes; second, the natural response to the impulse to purchase articles invitingly displayed by the progressive merchants. For instance, the average man will buy a pretty tie through the desire created by the sight of one, though the necessity of a tie may have been farthest from his mind when entering the street.

PRINCIPLES OF GOOD ILLUMINATIONS

The problem of good illumination for the business street is not unlike that of proper illumination for interiors and semi-interiors. The progress of lighting for the two latter requirements has found three steps. First, the use of unscientific units placed in a "hit or miss" manner and giving a light insufficient in quantity, improper in color, and of inefficient direction. Second, the use of sufficient illumination as given by the units of higher efficiency and candle-power. Many of them were not covered, thus causing glare and practically spoiling the effectiveness of the illumination. Third, the approximation of natural illumination by the combination of sufficient intensity with proper precaution to assure minimum glare and desirable color. The progress of interior illumination and semi-interior (show window) illumination has now reached the third stage through the use of diffusing globes, shades, reflectors, concealed lighting units, and indirect or semi-indirect systems.

To expect the same steps of progress in all classes of street lighting would be absurd, particularly so in residence or outlying districts, because here "street lighting" or "way marking" only is required. However, the problem of the business section has developed into one of "illumination," the ultimate results being similar to those of indoor illumination through close adherence to the same good qualities. This should come about by the use of proper mounting heights, illuminants of maximum efficiency and desirable color value, and efficient diffusing glassware. Although it will be impossible to make use of large diffusing surfaces, performing the same function as ceilings in the indirect and semi-indirect systems, this principle could be employed in some cases by concealing or partly concealing the light sources. There is an increasing tendency in business street illumination toward the development of the more subdued aesthetic qualities of interior illumination and away from the flashing brilliancy and the vulgarity of harsh glare. Through the advance made in high efficiency arc and incandescent lamps practically uniform illumination on the street and sidewalks is being obtained.

But little variance in opinion appears to exist on the question of illuminating the building faces. As the architectural appearance may be greatly altered by varying the direction, intensity, and color of light,* the illumination should be such as to produce an effect as near as possible to that produced by daylight. By taking into consideration the characteristics most probable in artificial illumination as well as in daylight, the architect would lend considerable to the improvement of our business streets. An illustration of such coöperation is found in the illumination of the building of the Denver Gas & Electric Company, Denver, Colorado, Fig. 1. The building is not only outlined by incandescent lamps but the facade and cornice details are made to stand out at night with wonderful detail.

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*"Light and Art," by M. Luckiesh, "Lighting Journal," March, 1913

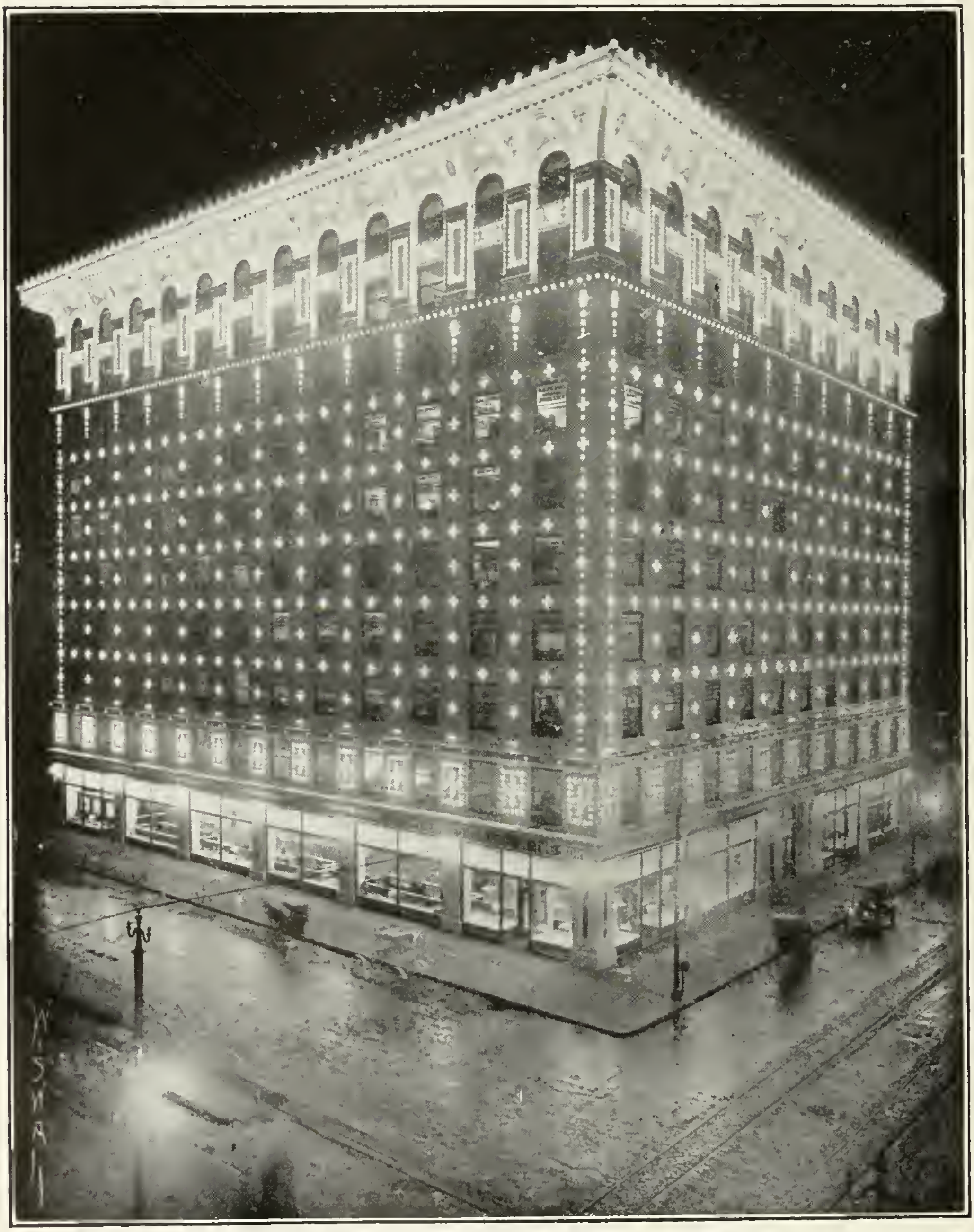

FIG. 1—ILLUSTRATION OF THE DENVER GAS & ELECTRIC COMPANY'S BUILDING, DENVER, COLORADO

An example of the results of coöperation of illuminating engineers and architects.

However, from the utilitarian point of view it is desirable to have a low illumination intensity on the building fronts as compared with the intensity on the streets. In fact, the employment of high intensity units, especially when mounted low, gives so much light in the direction of the display windows that a detracting effect is produced. The effect of the improved illumination on the display window is a serious consideration in such a case, as it requires an intensity on the displayed objects economically unobtainable. The ratio of the semi-interior illumination to the exterior illumination should be such that the whole window stands out clearly. The window, of course, will not be thoroughly effective without contrasty arrangement and complete elimination of bare lighting units. Fig. 2 shows such a window.

It is right for us to hesitate in suggesting the elimination of the present day electric sign from our modern "white way," but it is believed that business streets in the future will be made attractive by a type of different design, one more subdued and based on the artful control of light rays—their direction, intensity and color—upon objects or pictures, the light sources being completely concealed.* However, we do not wish to be interpreted as advocating the discarding of all bare lamp signs. It is suggested that these signs will be removed from the lower stories and found in large numbers on the roofs of buildings standing out clearly against the blackness of the night.

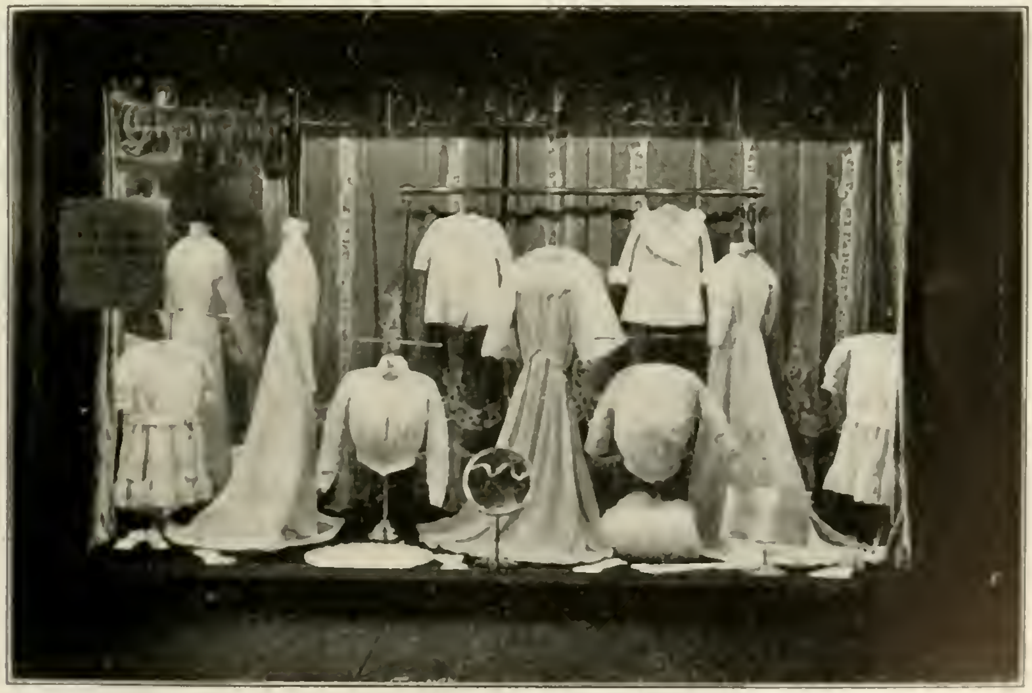

FIG. 2—EFFECTIVE WINDOW DISPLAY
The notable features are contrast and lack of glare.

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*"Light and Art," by Mr. M. Luckiesh, "Lighting Journal," March, 1913

NOTES ON STEEL MILL LIGHTING

C. E. CLEWELL

Department of Electrical Engineering, Sheffield Scientific School, Yale University

LARGE areas, dark surroundings, high roof trusses and extensive yards are features which must be given special attention by the electrical departments of steel mills when planning artificial lighting. The magnitude of the buildings makes the subject unusual and gives it an interest somewhat different from that of the lighting in smaller shops or factories. In an engineering investigation of lighting conditions in a number of steel plants, observations and tests were made in a large variety of locations, and this article describes some of the points of interest involved.

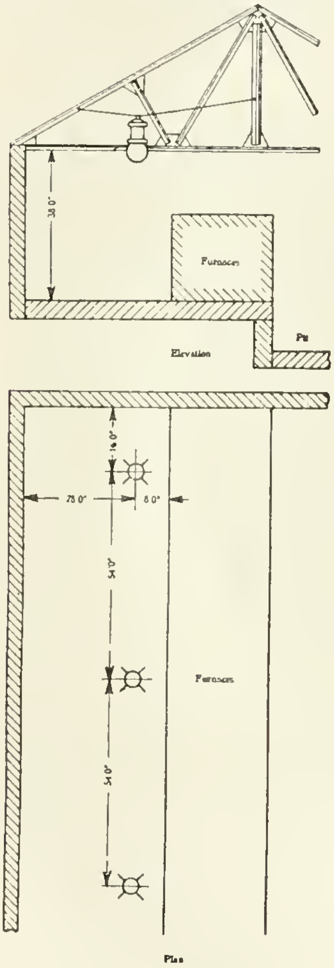

FIG. I

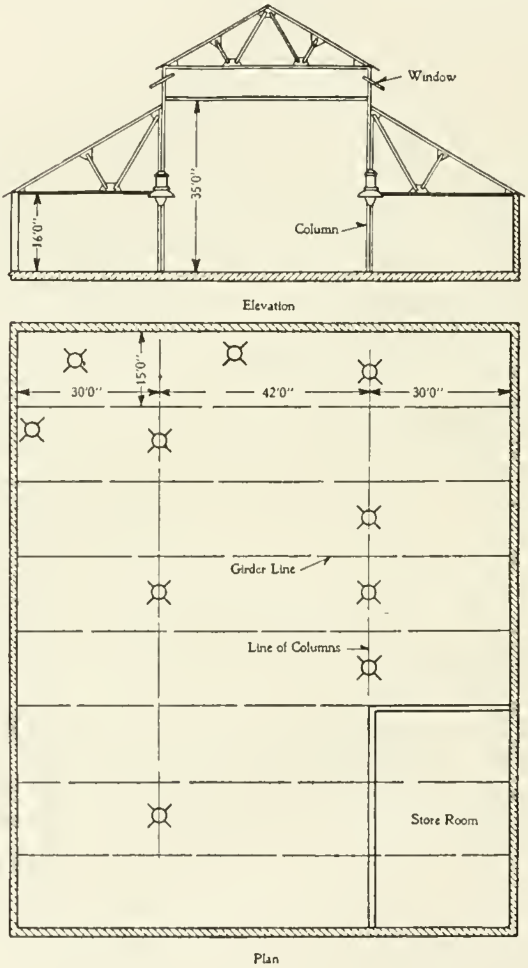

FIG. 2

FIG. I—PLAN AND ELEVATION OF OPEN HEARTH FURNACE BUILDING

Showing suggested arrangement for flame carbon arc lamps.

FIG. 2—POOR ARRANGEMENT OF LAMPS IN A REPAIR SHOP

The lamps are of the enclosed arc type and have been added from time to time as required.

The original application of electricity in most steel plants was for arc and incandescent lighting. Later electric motors were adapted to some of the operations, and the introduction of motors has had a considerable influence on the electric circuits installed. Thus, 220 volt direct-current circuits predominate in some cases to accommodate the variable speed direct-current motor. More recently alternating current has come into service, and its use will naturally increase as the alternating-current motor is applied to a larger variety of operations.

In some of the older mills where 220 volt direct-current is used exclusively, the lighting improvements are somewhat hindered by the limitations placed on the selection of the type of lamp. The power requirements are in general so much larger than those for lighting, that a change in the circuits to accommodate new types of lamps is not a popular consideration, although the many advantages of separate lighting circuits will doubtless result in the installation of suitable circuits to accommodate the type of lamp best adapted to particular conditions. These remarks refer especially to the mills visited, and conclusions are thus based on specific rather than general observations.

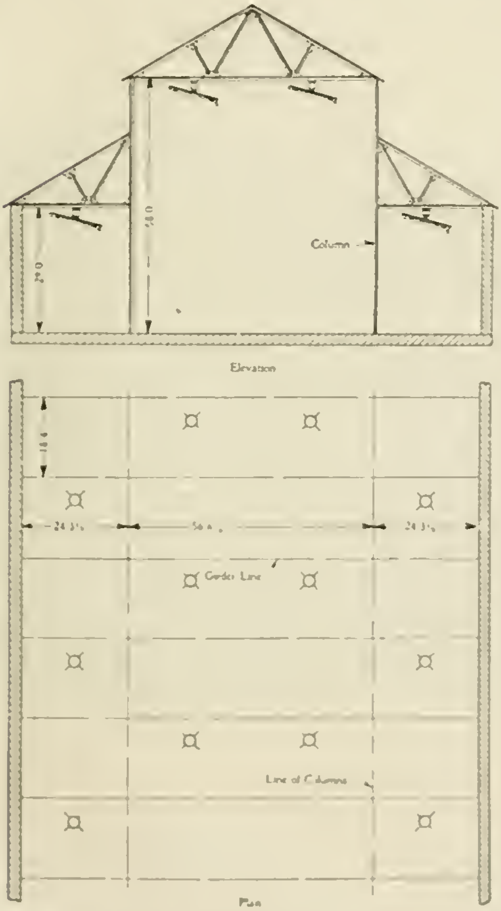

FIG. 3—LARGE MACHINE SHOP WHERE MERCURY VAPOR LAMPS ARE USED

The illumination is uniform but not adequate for close work unless an individual lamp is mounted on the machine.

Steel mill work covers such a wide range that several typical buildings are selected on which to base the discussion, as follows: Open-hearth furnaces, machine shops, foundries, pattern shopss and loading sheds, to which has been added yard lighting.

Taking these locations as a whole, several points deserve emphasis at the outset:

1—In many of the buildings illumination of low intensity from over-head lamps is all that is required to permit the workmen to get around without risk. The general illumination, however, should be considerably higher than is found in most cases at present.

2—Over-head lamps should be high enough to avoid glare, although the cranes nearly always makes this a necessary condition.

3—If the lighting circuits are kept entirely separate from power service, the illumination will be far more steady than otherwise. However, the power requirements are so large in comparison to the lighting that the tendency is to connect lamps to the power mains.

4—Much of the work makes it impractical for the workmen to be encumbered with hand lamps. In these cases adequate illumination from overhead lamps is an economic necessity.

5—The great variety of working operations requires a selection of the type and size of lamp suitable for the purposes involved.

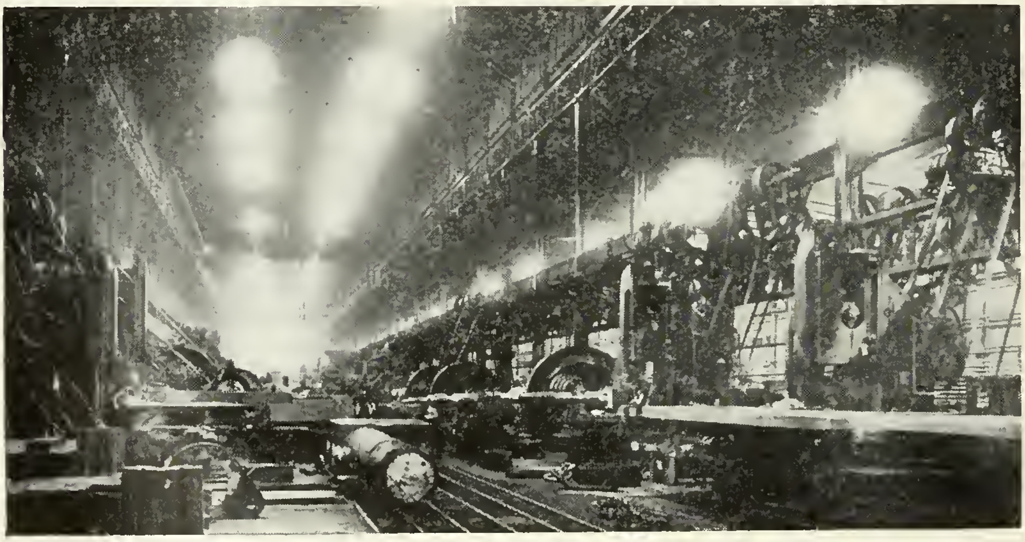

FIG. 4—REPRODUCED FROM A PHOTOGRAPH TAKEN AT NIGHT IN THE MACHINE SHOP SHOWN IN FIG. 3

6—The yards should be provided with lamps spaced to furnish a fairly uniform light of low intensity to facilitate the transportation of materials between buildings with dispatch and to prevent accidents. Guide posts with lamps are needed for walkways and passages, and the many gauges in the various buildings require small lamps properly shaded and placed.

OVER-HEAD LIGHTING MOST IMPORTANT

The matter of providing plenty of light from lamps mounted near the roof is one of peculiar difficulty, because of the very large areas coupled with the relatively small number of men often employed in given buildings. This feature makes it a question as to where the economy will be effected by installing a larger rather than a smaller number of lamps for a given floor space. As is usual in similar cases, the indirect advantages must be given due weight. Where the floor space is occupied by a relatively large number of workmen, the most apparent gain from superior light is in the wages saved for particular operations, or in the larger and better output for given labor expense. In many steel mills, however, the rating of the departments is based on tonnage output. A fairly large increase in lighting equipment would be warranted if it could be shown that the accompanying expense resulted in a small gross tonnage increase for the entire plant. Any increase in the output is influenced by so many factors that it is difficult to separate distinct advantages as a result of any one of these factors, like illumination. Steel mill superintendents realize, however, the general improved workmanship in buildings where adequate light is provided.

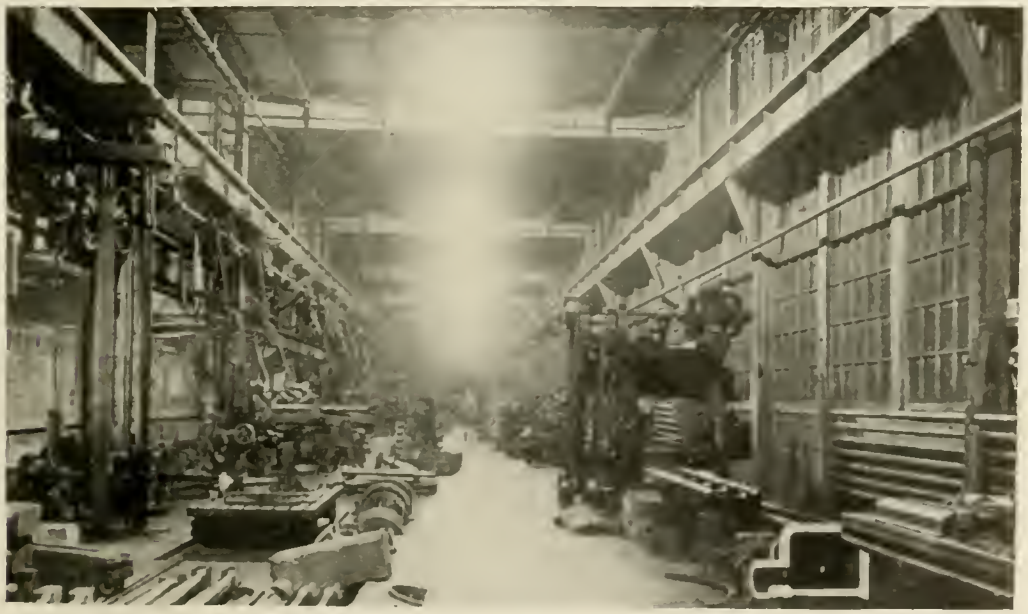

FIG. 5—MACHINE SHOP

Reproduced from a photograph taken at night in a machine shop where enclosed carbon arc lamps are used.

Again, defective work is often the cause of large losses, and this may result either in the operations themselves, or by the passing of a defective piece by an inspector, which must go through subsequent operations. Good light supplied just where needed will thus often more than pay for itself. These features, when taken in conjunction with other secondary advantages, will usually outweigh the objections raised against the equipment of the very large buildings with sufficient illumination from over-head lamps.

The foregoing economic relations become most important when one considers that many of the large steel mills have, during the past few years, installed over-head lighting systems in some of their largest buildings, which under test have proved to be insufficient for the proper lighting of the work. Most of these more recent installations are a great improvement over former conditions, but further advances are necessary before the general lighting of the various buildings is entirely satisfactory.

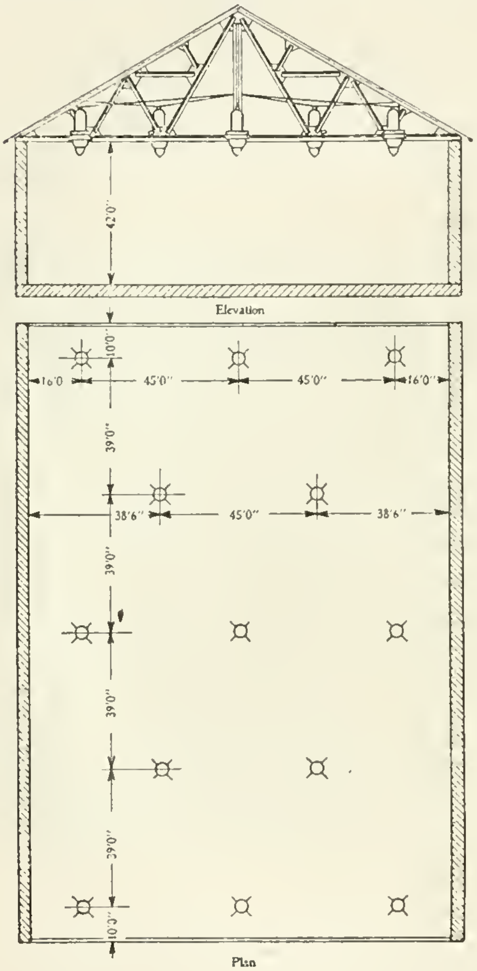

FIG. 6

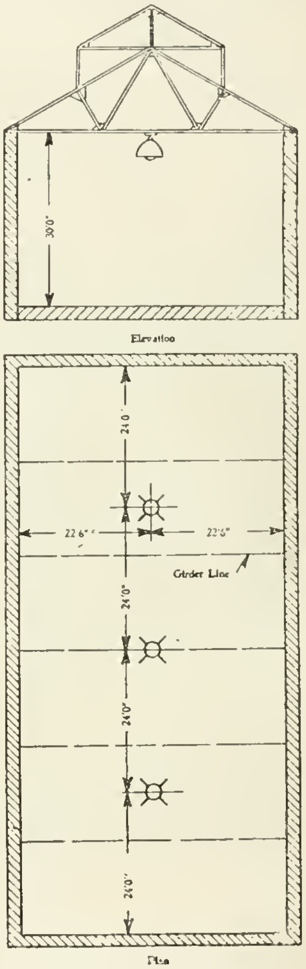

FIG. 7

FIG. 6—PLAN AND ELEVATION OF LARGE FOUNDRY
Showing suggested arrangement for flame cabon arc lamps.

FIG. 7—PLAN AND ELEVATION OF SMALL FOUNDRY
Using five hundred watt tungsten lamps with white enamel shades.

Another feature of a different kind connected with many present over-head lighting systems is in large discrepancies regarding standards of illumination intensity for given classes of work. While it is hardly practical to lay down hard and fast rules for the amount of light required for certain operations, it is an accepted fact that a fairly definite amount is needed for given forms of work. To find two sets of men engaged on similar work, and one group supplied with two and even three hundred percent more light than the other, is obviously an unfortunate policy. It is strongly recommended, therefore, that all lighting improvements be given study, so that the quantity of light furnished may be comparable with the needs of the case.

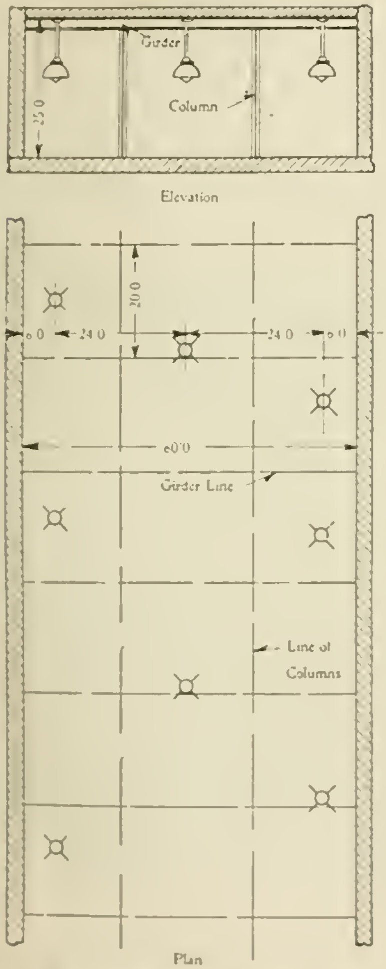

FIG. 8—PLAN AND ELEVATION OF A PATTERN SHOP

Five hundred watt tungsten lamps equipped with enamel shades are used.

OPEN-HEARTH FURNACES

The light from the furnaces themselves is an aid to the workmen in getting about. This light, however, is intermittent and the contrasts are great. While the amount of artificial light required is smaller than in a majority of the buildings, some general illumination is necessary to secure the most effective work and to reduce the liability of accidents. In some open-hearth buildings, the space back of the furnaces is used for loading purposes, and here the light from the furnaces is usually not sufficient to be of much use. Fig. 1 shows the plan and elevation of a portion of an open-hearth furnace building, where the arrangement of lamps has been planned for a moderate illumination intensity, sufficient to meet the requirements when the light from the furnaces is low. The illumination furnished on the floor space in some of these buildings amounts to only a small fraction of one foot-candle by test, but where the lamps are so widely scattered as to result in these very low intensities, the artificial light at night is practically useless and the workmen must depend altogether on the intermittent light from the furnaces, or get about with difficulty under the meagre light from the few arc lamps. The fact that work is conducted at night under such conditions is no argument against the installation of better lighting, because it is obvious from observations that better and more rapid work would be quite possible if the men were able to see where they are walking all of the time.

MACHINE SHOPS

Sometimes the machine shop is merely an auxiliary to the steel plant where repair work is done from time to time. In other cases the output of the plant consists of machine shop construction. In the latter, artificial light has a definite place in the economy of production. Fig. 2 shows the plan and elevation of such a building where repair work is performed. This work is intermittent, and varies so that the shop is sometimes crowded with workmen and at other times the work is slack. Due to this feature the lighting has followed no definite plan, but arc lamps have been added here and there, as required. The illustration shows the very irregular arrangement of lamps which is apt to result when no system is observed in the placing of lamps, and in this particular location the light is poorly distributed, and so inadequate near the two side walls that work on the benches along these walls is practically an impossibility at night.

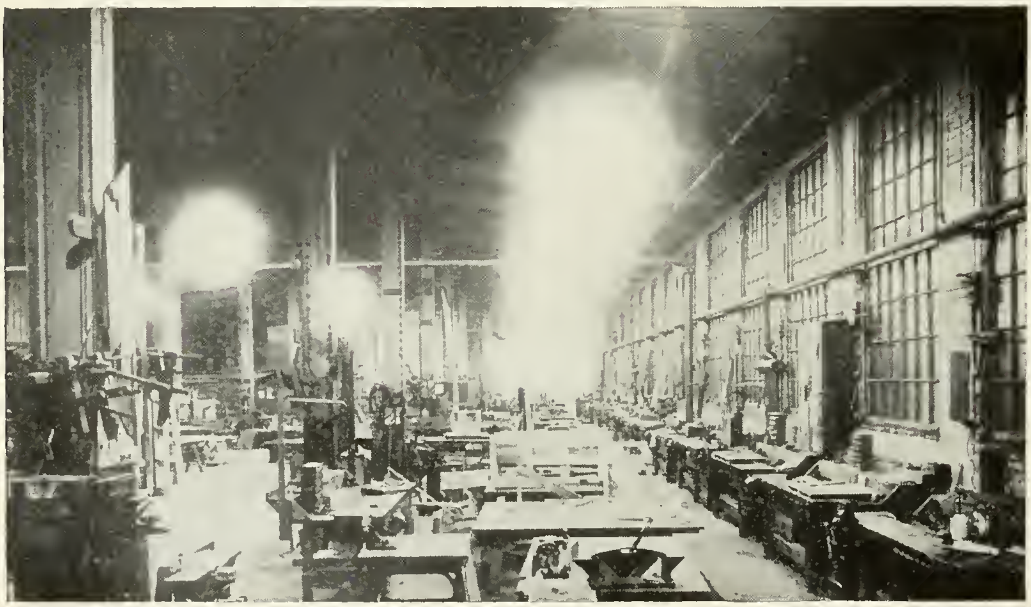

FIG. 9—REPRODUCED FROM A PHOTOGRAPH TAKEN AT NIGHT UNDER THE TUNGSTEN LAMPS AS SHOWN IN FIG. 8

A shop where some of the important operations connected with production are carried on is shown in Fig. 3. The central aisle is very high and the building as a whole consists of some twenty or thirty bays of the size shown in the illustration. Here the lighting has been carefully planned and tests show it to be uniform, but inadequate for close work, unless individual lamps are placed on the machines. Tests show that the illumination intensity on the working plane is about one foot-candle, while the intensity directly under an individual lamp amounts to about five foot-candles. It is a question whether enough lamps could economically be provided here to make the use of hand lamps unnecessary. The floor area is so large and the mounting height so great that adequate light on the work would mean a very much larger expenditure for overhead lamps. On the other hand, it would be decidedly advantageous to plan such an installation so as to furnish intensities of higher value to the work. One foot-candle is hardly sufficient for even coarse work, and the many operations which call for freedom from hand lamps could be much easier carried on if more over-head lamps were available. Fig. 4 is reproduced from a photograph taken under the artificial light in the location of Fig. 3. From this illustration tration some idea can be gained of the uniformity of the light on the work and the relatively low shadow effect. Fig 5 is a view of another shop where enclosed carbon arc lamps are used successfully.

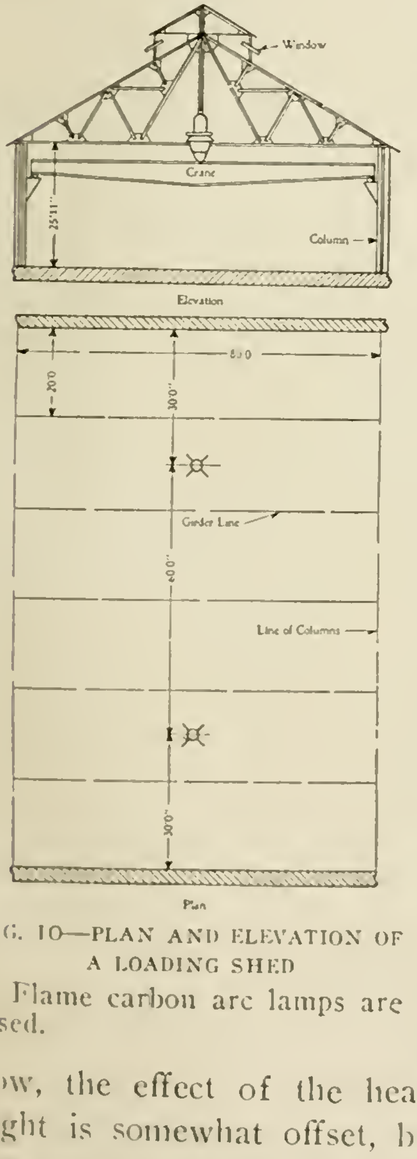

FIG. 10—PLAN AND ELEVATION OF A LOADING SHED

Flame carbon arc lamps are used.

THE FOUNDRY

The presence of steam, dust and dirt in the air makes the lighting of these buildings difficult. Where the lamps may be mounted comparatively low, the effect of the heavy dusty atmosphere in reducing the light is somewhat offset, but for high mounting the lamps must be capable of penetrating the dust and steam, and should not rapidly deteriorate with the accompanying accumulations of dirt on the lighting units. The mercury vapor lamp and the flame carbon arc lamp have proved to be well adapted to many foundries. In some cases the tungsten lamp is used, but its deterioration with dirt accumulations makes it somewhat less suitable for the majority of cases.

The dark surroundings and the nature of the work with the dark surfaces and deep openings makes it necessary to consider a high intensity of illumination and to furnish adequate light on the sides of the work with as little shadow as possible. It is apparent that slight shadows may be an advantage in the finishing of the moulds, specially when certain uneven places must be detected, but the heavy shadows cast by a man when the light is received from a single intense lamp, should be avoided by using several lamps to illuminate each portion of the work. In other words, a relatively large number of medium sized lamps is here preferable to a small number of very large lamps.

To provide against deterioration of the lamps from dust and dirt, the lighting should be of a somewhat higher intensity than necessary at the start, thus allowing a factor of safety. This feature will help in the maintaining of adequate intensities, but the regular upkeep of the lamps in renewals, cleaning and repairs, is also very necessary. Fig. 6 shows the design suggested for a large foundry by means of the flaming carbon arc lamp. The arrangement of the lamps is symmetrical and the mounting height brings the lamps well above the line of vision. Fig. 7 shows a small foundry building, where there is not much dirt in the air, and here 500-watt tungsten lamps are used with satisfaction.

PATTERN SHOPS

A pattern shop is found in conjunction with nearly all steel mills, and it is usually the one building where the surroundings are bright and relatively clean. The natural surfaces of the work, being light in color, make the lighting problem quite simple. Tungsten lamps possess many advantages in connection with these buildings, and Fig. 8 shows a typical floor where the lamps are not arranged entirely symmetrically, but so as to take care of the main portions of the work. Five-hundred watt lamps are employed with white enamel shades, and the effect is very satisfactory. Fig. 9 is reproduced from a photograph taken under the lamps shown in Fig. 8. Tests show the average intensity of the illumination to be two foot-candles in this location, and the light is fairly uniform, notwithstanding the fact the lamps are spaced somewhat irregularly.

LOADING SHEDS

Where much of the output consists of rolled iron, boiler heads, and other shapes, the material is stored in sheds, commonly called "loading banks," into which the cars are run for loading. The work, while intermittent, is usually carried on with dispatch to prevent delays in holding the cars, as well as for quick shipment. The floor areas are often large, but the number of men employed relatively small. Moreover the work is apt to be localized at certain banks of material, so that general illumination over the entire building is not required at all times.

Due to the large areas, the lamps are generally spaced far apart, and the light is thus poor at all places. To offset this difficulty, a more liberal number of lamps is needed with a switching arrangement, so that lamps in unused portions of the floor may be turned off. In this way, the space being used at any one time can be furnished with plenty of light and the work made correspondingly easier. Another feature in the handling of heavy shapes, is the risk of accidents at night, and this risk is much reduced if adequate light is available. A plan and elevation of a typical loading bank, where large lamps of the flame carbon type are used, is shown in Fig. 10. The lighting is fairly uniform here, but the shadows are very marked and are objectionable in the corners of the building. The effect would be very much improved by the use of more lamps of smaller size, although the scheme indicated in the illustration answers quite well for ordinary purposes, and especialy so where the work is not steady in any one place. Tests show the average intensity of the illumination here to be about one and one-half foot-candles.

YARDS

The yards about steel mills are often used a great deal at night for the shifting of cars, and the transportation of materials between buildings and away from the plant. In the larger mills the yards have become so vast that the problem of sufficient lighting is one real help in the work carried on there. Fig. 11 will give some idea of the spacing distances between lamps found in practice. This installation is not intended to serve as a standard, for the light in this particular instance is poorly distributed, and there are many dark corners and dangerous passages. The diagram does show, however, a good scheme for laying out the yard in diagrammatic form, and on such a diagram the poles for the lamps may be spaced with regard to the entrances to buildings and the storage of materials.

In one large yard the quartz mercury vapor lamp is being used successfully. These lamps possess a very high candle-power, and are mounted on poles 60 feet above the ground. Tests under these lamps show an excellent distribution of the light over a large area for each lamp, the appearance to the eye at night being somewhat similar to bright moonlight.

GENERAL ITEMS

From numerous tests made in the various buildings of the plants visited, Table I has been compiled. The engineering data contained in this table gives an idea of the intensities of light which are being used in many of the mills, and the general statement may be made that these intensities are considerably lower than is required for the various operations. In comparison with former conditions, however, the present lighting facilities represented by the tests are in many instances great improvements. The presence of red hot metal in some of the buildings and in the yards is some- of considerable expense if the light is to be sufficient to serve as a times used as an argument against the introduction of better lighting. The light from hot metal is intermittent and the contrasts are correspondingly great, making the dark periods more noticeable than otherwise. For taking account of the dark intervals and for preventing accidents, artificial light in reasonable quantities should be furnished even where some light is available from the metal.

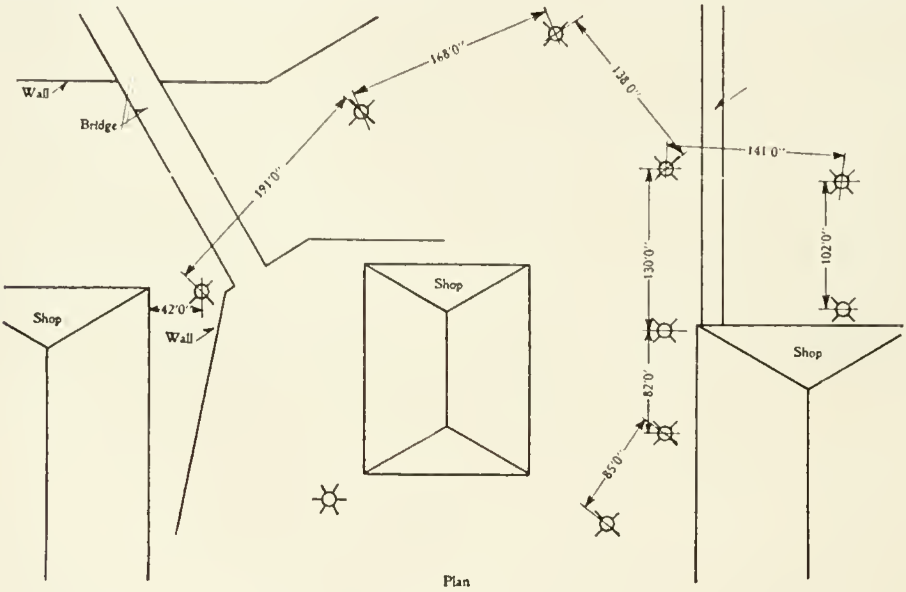

FIG. 11—PLAN OF YARD

Showing the arrangement of arc lamps, and some of the spacing distances found in practice.

In perhaps no other class of work is there so much dust and dirt present. Lamps of all types suffer rapid deterioration under the circumstances, and the necessity for systematic upkeep is even greater than in other plants. Maintenance is apt to be neglected, un-

TABLE I—ENGINEERING DATA FROM ACTUAL LIGHTING SYSTEMS IN TYPICAL STEEL MILL LOCATIONS

Location	Type of Illuminant	Mounting Height above Floor	Watts per Square Foot	Average Foot-Candles	Condition of Surroundings	Remarks
Cooling Tables and Laying Out Floor	Mercury Vapor	23'-10"	0.461	0.62	No roof; Dark walls	Fairly adequate
Loading Bank	Enclosed Arc	27'-1 "	0.235	0.153	Dark roof; Dark walls	Entirely inadequate
Flanging Department	Flame Carbon Arc	27'-6 "	0.099	0.32	Dark roof; Dark walls	Fairly satisfactory
Flanging Department	Mercury Vapor	30'-1 "	0.513	0.111	Dark roof; Dark walls	Very poor
Loading Bank	Flame Carbon Arc	25'-1½"	0.126	0.43	Dark roof; Dark walls	Intensity adequate; Shadows rather marked
Cooling Tables and Laying Out Floor	Mercury Vapor	23'-10"	0.740	0.50	Dark roof; Dark walls	Illumination satisfactory directly under lamps
Power House	250 Watt Tungsten	33'-9"	0.587	0.936	Medium ceiling; Light walls	Illumination sufficient for intermittent work
Machine Shop	4-60 Watt Tungsten Clusters	21'-0"	0.378	0.38	Medium ceiling; Light walls	Hardly sufficient for continuous work
Open Hearth Pitt	Enclosed Carbon Arc	20'-3"	0.873	0.14	Dark ceiling; Dark walls	Very poor
Cooling Tables and Laying Out Floor	Flame Carbon Arc	27'-0"	0.367	0.42	Dark ceiling; Dark walls	Fair
Cooling Tables and Laying Out Floor	Flame Carbon Arc	27'-0"	0.338	0.54	Dark ceiling; Dark walls	Fair
Flanging Department	Flame Carbon Arc	30'-0"	0.091	0.096	Dark ceiling; Dark walls	Very poor
Machine Shop	Mercury Vapor	28'-0"	0.401	0.390	Dark ceiling; Dark walls	Uniform, but intensity somewhat insufficient
Yard	Quartz Mercury Vapor	61'-6"	....	0.075	On Horizontal Plane	Fair
		30' 0"	....	0.070	On Normal Plane	
Projectile Shop	Mercury Vapor	15'-0"	0.481	0.663	Dark ceiling; Light walls	Satisfactory
Carpenter Shop	500 Watt Tungsten	15'-0"	0.514	1.02	Dark ceiling; Dark walls	Sufficient for ordinary operation
Pattern Shop	500 Watt Tungsten	11'-6"	0.791	1.51	Dark ceiling; Dark walls	Good
Machine Shop	Mercury Vapor and Enclosed Arc	....	0.601	0.757	Dark ceiling; Dark walls	Fairly satisfactory
Yard	Enclosed Arc	12'-0"	....	0.105		Inadequate
Power House	60 Watt Carbon Lamps	14'-0"	0.985	0.15		Very poor
Blooming Mill	Enclosed Arc	13'-0" to	0.262	0.591	Dark ceiling; Dark walls	Very poor
Yard	Enclosed Arc	15'-0"	....	0.118		Inadequate
Open Hearth Furnaces	Enclosed Arc	38'-0"	0.446	0.066	Dark ceiling; Dark walls	Inadequate
Machine Shop	Enclosed Arc	14'-0"	0.664	0.327	Dark ceiling; Dark walls	Inadequate and distribution very poor
Ingot Mould Foundry	500 Watt Tungsten	30'-0"	0.347	0.296	No ceiling; Clean brick walls	Intensity not sufficient
Machine Shop	Enclosed Arc	22'-6"	0.484	0.252	Light ceiling; Dark walls	Distribution good; Intensity somewhat low
Erecting Shop	Mercury Vapor	55'-0"	0.401	0.321	Dark walls; Dark ceiling	Hardly sufficient for continuous work
Power House	Mercury Vapor	45'-0"	0.622	0.597	Rather dark ceiling and walls	Good
Iron Foundry	Enclosed Arc	11'-0"	0.701	0.233	Dark walls; Dark ceiling	Insufficient

less there is a regular department for taking care of the work, and to this end, it is recommended that the electrical departments connected with steel mills adopt the method of inspecting and maintaining of electric lighting apparatus which has proved so beneficial in other manufacturing plants.

Aside from the regular buildings there is generally a power house, often of large size, in connection with the steel plant. One of these power houses is shown in Fig. 12, where mercury vapor lamps are mounted 45 feet above the floor. It is of interest to note that the instruments on the switchboard on the right of the illustration can be read at night with ease from the light furnished by lamps 45 feet overhead. The distribution of the lamps is so well arranged that the entire room is well lighted.

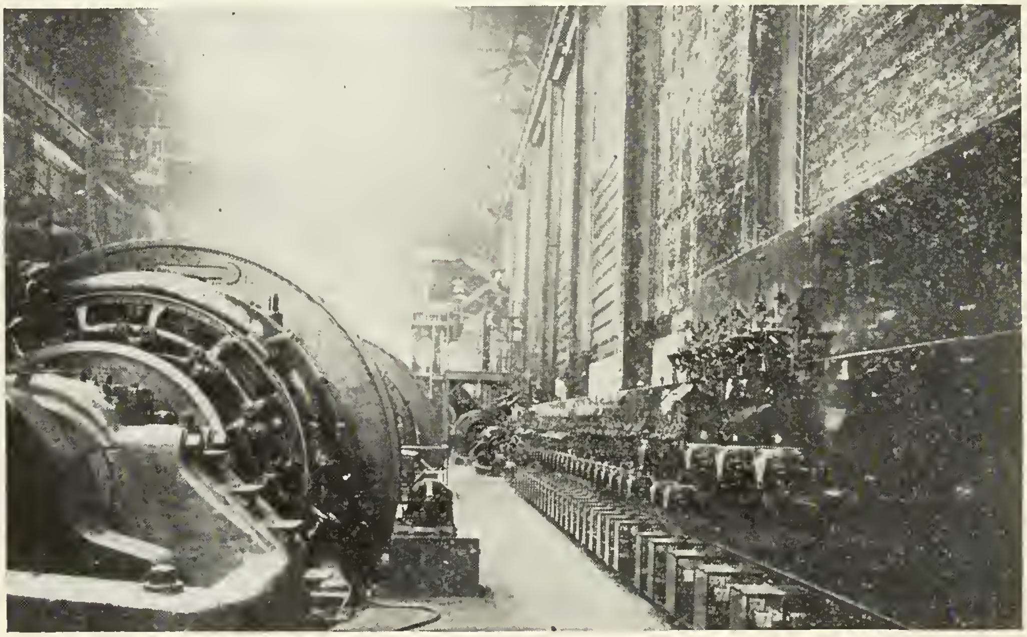

FIG. 12—POWER STATION

Reproduced from a photograph taken at night under the light from mercury vapor lamps mounted 45 ft. above the floor.

The electrical department of a steel mill is a well defined portion of the plant organization. Such departments have the opportunity to inform those responsible for the outlays for lighting equipment as to the many indirect advantages of adequate illumination. Attention to these indirect advantages should become a study with the heads of such departments, and as they become more familiar with the influence of good light on the various operations of the plant, a new viewpoint thus gained will undoubtedly result in higher standards of light than are found in most of the mills at the present time.

A TWO-AND-A-HALF-BILLION DOLLAR ARGUMENT FOR CENTRAL STATION SERVICE

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Industrial Engineering Company, Pittsburgh, Pa.

EITHER a two-and-a-half-billion dollar mistake has been made by some of the ablest business brains in the United States, or else the central station principle of power production is right and the isolated plant principle is wrong. Twenty-five hundred million dollars is the total capital now invested in electric power companies, and this does not include electric railways. Two billion, five hundred million dollars is more than the total capitalization of any one manufacturing industry in this country except iron and steel. It is not likely that all of the men handling this tremendous investment have made a mistake. This investment has not been incurred principally to develop residential lighting, as may be seen from Table I, which is based on the latest census data.

TABLE I—COMPARISON OF CENTRAL STATION CONDITIONS

Items	1902	1907	1912	Percent increase in 10 years
1—Number of central stations in U. S....	3 620	4 712	6 128	69.4
2—Combined capital...	$504 740 352	$1 096 913 622	$2 500 000 000	397
3—Combined primary horse-power capacity	1 830 594	4 032 365	9 476 057	417
4—Total income from commercial lighting.	$70 138 147	$ 125 755 144	$ 238 974 716	226
5—Total income from power	$ 9 910 217	$ 28 511 550	$ 85 534 650	764
6—Gross income .(Includes street lighting. etc.)...........	$85 700 605	$ 175 642 338	$ 377 630 811	340

Item 2 shows that the combined capital of the central stations in this country has increased practically 400 percent during the last ten years. In other words, four-fifths of the present investment has been made during this period. Item 3 shows that this increase has been accompanied by a corresponding increase (417 percent) in the primary horse-power of central stations. Power can only be produced by machinery and machinery must be paid for. The fact that the cost of the additional machinery required to produce the additional horse-power corresponds roughly with the increase in capitalization, indicates that the increase in capital was not simply an increased issue of stock. Items 4 and 5 show that while the income from commercial lighting has increased 226 percent during the past ten years, the income from industrial power has increased 764 percent. As every central station man knows, the possibilities of profit from power business are considerably greater than from lighting. It is evident, therefore, that the enormous investment of capital in electric utilities is based on the increasing demand for the advantages of central station power.

TABLE II—TOTAL OF ALL MANUFACTURERS

Items	1902	1912	Percent increase in 10 years
1—Number of establishments....	212 700	276,500	50
2—Capital	$11 195 447 000	$22 800 000 000	105
3—Primary horse-power to operate establishments............	12 131 800	22 550 000	86
4—Number of wage earners....	5 166 100	7 230 000	40
5—Wages	$ 2 369 611 400	$ 4 051 000 000	71
6—Number of salaried employees	457 380	988 000	116
7—Salaries	$ 496 971 800	$ 1 220 000 000	146
8—Cost of material.............	$ 7 730 465 200	$14 300 000 000	85
9—Value of finished products...	$13 439 112 600	$24330 000 000	81
10—Value added by manufacturers	$ 5 708 647 400	$10 030 000 000	76

There is every reason for manufacturers to be interested in central station service at the present time. The manufacturer is constantly being brought face to face with the problems of higher wages, higher salaries and higher cost of raw materials. To maintain the same margin of profit he must either raise the selling price or lower the cost of production. Any increase in selling price means less business for him and more business for his com-

TABLE III—NUMBER OR VALUE PER ESTABLISHMENT

Items	1902	1912	Percent increase in 10 years
1—Number of establishments....	212 714	276 500	30
2—Capital	$ 52 600	$ 82 500	57
3—Primary horse-power to operate establishments	57	81.5	43
4—Number of wage earners....	24.3	26.2	7.5
5—Wages	$ 11 130	$ 14 680	32
6—Number of salaried employees	2.15	3.57	66
7—Salaries	2 345	$ 4 420	88.5
8—Cost of material.............	$ 36 350	$ 51 700	42.0
9—Value of finished products...	$ 63 150	$ 88 100	39.5
10—Value added by manufacturers	$ 26 800	$ 36 400	36.0

petitors. It is necessarily a last resort. Therefore, any genuine opportunity to reduce his production cost, should have careful attention.

The manufacturers' situation may be clearly understood from Tables II and III. The figures in Table III were derived from those in Table II and show the present situation in its relation to each individual manufacturer. The uniformly prosperous condition of American industry is shown by the average increase of 57 percent in capitalization per establishment. Item 3, which shows an increase of 43 percent in installed primary horse-power, indicates that this increase in capitalization is a genuine increase in value. The number of wage earners has increased only 7.5 percent, due undoubtedly to the increased use of improved machinery and increased efficiency. Wages, however, have increased 32 percent—more than four times as rapidly as the number of wage earners. This means that workmen everywhere are getting a good deal more money than they did ten years ago. Incidentally, this is also a definite answer to the assertion, often heard, that wages have not risen with the rise in prices. Item 6, showing an increase of 66 percent, indicates that the increasing complications of modern industry are making more salaried men a necessity. Salaries have increased 88.5 percent in the same time. In other words, there are more saalried men than formerly and they are being paid more money per man. This is another expense that must be provided for by raising the selling price or introducing new economies. The increasing price of raw materials must also be considered.

All of these changes, it must be remembered, are taking place as rapidly now as they have been during the last ten years. The manufacturer is facing them now and, if central station service will bring him closer to a solution of the problems they have developed, he needs this service just as much as the central station wants to sell it.

The advantage of central station power over any other for the small plant is pretty well established. The advantage of this service to the large manufacturer is not so obvious, and has not been nearly so well established. Large manufacturers, with few exceptions, imagine that simply because of their size, they should be able to produce power as cheaply as a central station, and there are still a few central station men left who think the same way. This impression is wrong. The large manufacturer can make power more cheaply than the small manufacturer, but not as cheaply as the central station. To begin with, the larger size of the central station gives it the same advantages over the large manufacturer that he has over the small manufacturer. In addition to this the central station, regardless of its size, has inherent opportunities for economies that are entirely beyond the reach of the average manufacturer.

In the first place, the manufacturer's business is manufacturing. The superintendent of a shoe factory, for example, is selected because he knows how to make, at a low cost, shoes that will sell in competition with other shoes. His training has been along these lines. The production of power is a business in itself, far more complicated than the manufacture of shoes. He can never give it the same attention that the central station organization does, nor can he understand it nearly as well. Furthermore, he cannot afford to hire the quality of brains that efficient power production demands. It is a natural consequence that the average isolated plant is less efficient than the average central station.

Second, the time that the shop executive gives to an isolated plant must be taken from other work. It is at this other work that the superintendent is most efficient, and it is on this work that the dividends of the concern depends. Power ordinarily represents about two percent of the total cost of production. The use of an isolated plant compels the superintendent to devote to this two percent, time that could be spent much more efficiently on the remaining 98 percent. All of the time that he spends in trying to maintain the efficiency of the power plant involves a reduction in the efficiency of manufacturing. This is a feature of isolated plant cost that it is difficult to show in definite figures but that must be paid for from the concern's gross receipts.

Third, the central station necessarily has a better load factor and diversity factor than has the isolated plant. The isolated plant must be built for the maximum load of one establishment. The central station, by supplying many different kinds of demand, secures an average load that is much nearer to the maximum. This means that less generating equipment will be needed for the same power output.

The advantage that central station service has over isolated plant service is at the present time being increased by the steadily advancing price of coal. Table IV shows the changes that have taken place in the average price of bituminous coal since 1880. Thus the price of coal has increased over ten percent during the past ten years, and this, it must be remembered, is only the average increase. In some parts of the country the increase has been as great as 25 percent.

The position of the central station is strengthened still more by the increasing demand for power. The census figures given in Table II show that this demand has increased 86 percent in the last ten years. This means that many new concerns requiring power are coming into existence and that many old ones are finding it necessary to enlarge their present power equipment. Every manufacturer who is considering a new power plant or extensions to an old one is a candidate for central station service. The first cost of a central station power installation is always much less than the first cost of an isolated plant. Also extensions are less expensive. The money for an isolated plant can ordinarily be secured only by bringing the concern that uses it nearer to the limit of its borrowing capacity. The average concern can make the largest dividends by using all of the money it can borrow, for the productive end of the business. The money tied up in a power plant is taken from the work for which the concern was organized, and which is presumably the most profitable. If the money invested in the power plant has not as great an earning capacity as the money invested in productive equipment, then the power plant represents a loss. In other words, *an isolated plant does not pay, even if it delivers power as cheaply as the central station.*

TABLE IV—COMPARATIVE PRICES OF BITUMINOUS COAL

Year	Average price per ton	Percent increase in price
1880	$1.048	——
1890	1.123	7.15
1900	1.140	1.52
1910	1.257	10.26

These figures were obtained from the U. S. Geographical Survey.

Due to the increasing age of their present power generating machinery, many manufacturers are now compelled to consider a new investment in plant equipment. Many plants are equipped with apparatus that has been in use for fifteen or twenty years or more, and that is now operating very inefficiently. Often, the owner does not realize how much this inefficiency is costing him. In many cases, however, he is thoroughly aware of the conditions but dreads the investment that a change would involve. By using central station service, he can get higher efficiency than he could with a new isolated plant and get it at a lower cost.

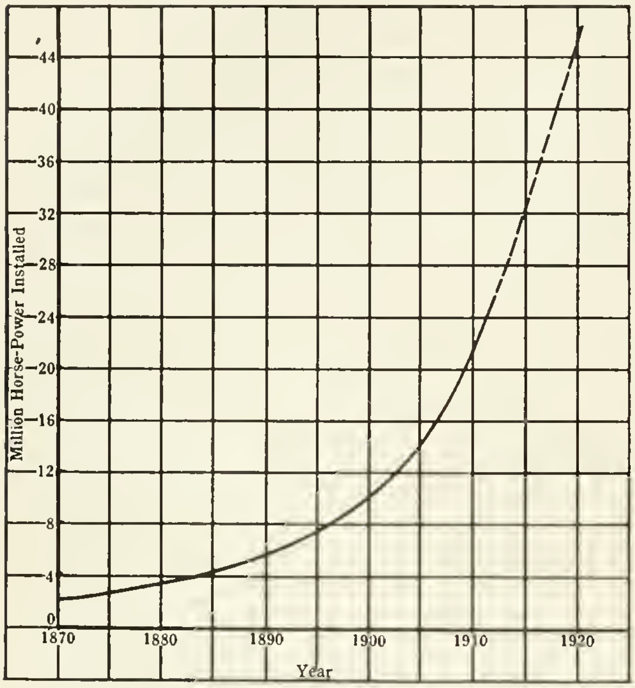

FIG. 1—CURVE OF HORSE-POWER INSTALLED FOR MANUFACTURING PURPOSES

Dotted lines indicates probable future growth.

The remarkable opportunity now before the central stations of this country is well brought out by the accompanying curves, Figs. 1 and 2. Fig. 1 illustrates clearly the tremendous rapidity with which the demand for power in manufacturing plants is increasing. It will be seen that this demand has risen from little more than two million horse-power in 1870 to about 25 million today. While it is, of course, impossible to determine accurately how rapidly this demand will continue to increase, there is every reason to believe that the rate of increase indicated by the dotted line is conservative. The growth of power requirements during the next eight years will certainly continue as rapidly as at present and it is on this assumption that the curve has been extended. In other words, we may expect to see the use of power increased to about 47 million horse-power by 1920. This means that an additional 22 million horse-power will be put in service during the

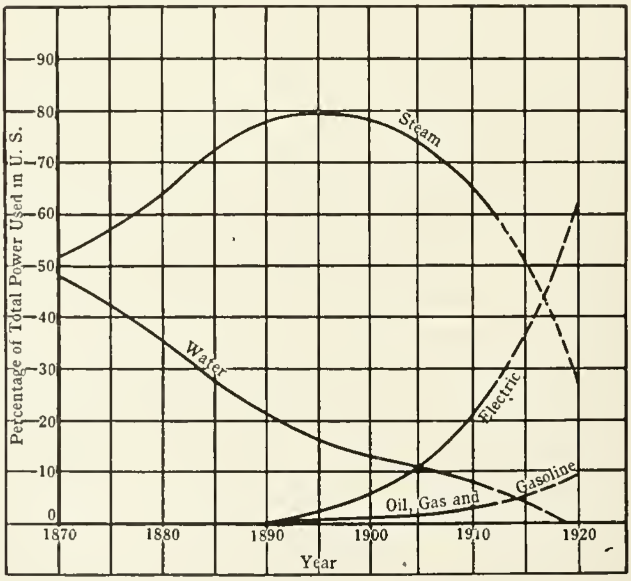

FIG. 2—CURVES OF PERCENTAGES OF TOTAL POWER SUPPLIED BY VARIOUS MEANS

Dotted lines indicate probable future percentages.

next eight years. Most of this power is going to be electric. The curves in Fig. 2 show why. These curves give the percentage of different kinds of power used by manufacturing plants in this country. Each curve refers to the power applied directly to productive machinery. The curve for water power, for example, does not take hydro-electric plants into consideration. It covers merely the power delivered directly from water wheels to productive machinery. These curves show that electric power is rapidly replacing all other kinds, but that it has just started to do so. Ten years ago not more than eight percent of the total power used in the manufacturing plants of this country was electric. Now electric motors furnish 27 percent of the driving power. If the present rate of increase continues, and there is absolutely no reason to believe that it will not, we may expect to see more than 60 percent of the total power used in manufacturing in 1920 furnished by electric motors. As already indicated the total power will amount to about 47 million horse-power by that time. Sixty percent of this amount is 28 200 00. At present the total power demand amounts to 25 million horse-power, and of this 27 percent is electric power. Twenty-seven percent of 25 million is 6 750 000. The difference between 28 200 000 and 6 750 000 is 21 450 000. In other words, we may expect to see about 21 500 000 electric horse-power installed during the next eight years. This is almost as much as the total power in use at the present time. Fig. 3 shows the situation graphically. Practically all of this power should be furnished from central stations, and it will be, if the right steps are taken to get it.

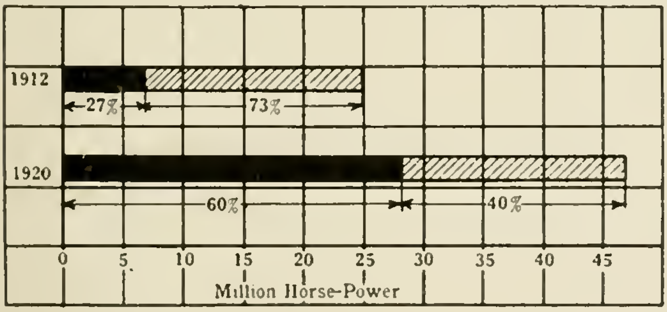

FIG. 3—PRESENT AND PROBABLE FUTURE INSTALLED HORSE-POWER IN UNITED STATES

Black area represents installed electrical horse-power. Shaded areas represent other installed horse-power.

There would be comparatively few isolated plants in existence now if the owners knew just what it cost them to get their power that way. The average isolated plant owner, however, knows very little about his power costs. To begin with, it is often found that he estimates his power consumption much higher than it actually is. He thinks that this is the amount of power he will have to pay for if he uses central station service. Usually, too, he makes no allowance for overhead cost. In short, his manufacturing experience does not ordinarily fit him to understand power.

Central station service cannot have a fair chance unless it is brought face to face with facts. The central station can deter- industrial power. The results of a number of actual investigations mine the facts in only one way—by a thorough analysis of the prospect's plant, made by engineers who thoroughly understand are shown in Tables V to X. The plants in which these investigations were made all come within the class of big consumers, as the yearly power consumptions indicate. Yet, in every one of them, central station service meant a very decided saving.

TABLE V—RESULTS OF INVESTIGATION AT A COAL PIER

Capacity 10 000 000 tons coal per year.

Item.	With Isolated plant.	With Central Station Service.	Saving through Central Station Service.
Consumption kw-hr per annum...	4 330 000	4 330 000	......
Cost per kw-hr..................	$ 0.0145	$ 0.0132	$ 0.0013
Cost per ton of coal...........	$ 0.0042	$ 0.00382	$ 0.00038
Operating charges per annum..	$63 091	$57 495	$ 5 596
Fixed charges per annum.......	$27 280	$26 145	$ 1 135
Total expenses per annum......	$90 371	$83 640	$ 6 731

TABLE VI—RESULTS OF INVESTIGATION AT A MACHINERY MANUFACTURING ESTABLISHMENT

Item.	With Isolated plant.	With Central Station Service.	Saving through Service. Central Station
Cost per kw-hr................	1 610 000	886 000	724 000
Consumption kw-hr per annum.	$ 0.0346	$ 0.02	$ 0.0145
Operating charges per annum..	$60 032	$17 720	$42 312
Fixed charges per annum......	$19 600	$ 4 450	$15 150
Total expense per annum.......	$79 632	$22 170	$57 462

TABLE—VII—RESULTS OF AN INVESTIGATION OF A TANNERY

Item.	With Isolated plant.	With Central Station Service.	Saving through Central Station Service.
Consumption kw-hr per annum.	1 696 000	1 252 700	444 300
Cost per kw-hr................	$ 0.0242	$ 0.011	$ 0.0132
Operating charges per annum..	$37 611	$25 906	$11 705
Fixed charges per annum......	$ 7 723	$ 2 836	$ 4 887
Total expense per annum.......	$45 334	$28 742	$16 592

In the machinery manufactury, Table VI, and in the tanneries, Tables VII and VIII, big reductions in the power consumption as well as in the cost per kw-hr. were effected. Many leather manufacturers and some central station men believe that tanneries can produce power as cheaply as they can buy it, because they not only use "spent tan" for fuel, but can utilize exhaust steam. The figures given in Tables VII and VIII show conclusively that tanneries can use central station power advantageously.

TABLE VIII—RESULTS SECURED AT ANOTHER TANNERY

Item.	With Isolated plant.	With Central Station Service.	Saving through Central Station Service.
Consumption kw-hr per annum.	630 000	447 200	182 800
Cost per kw-hr................	$ 0.028	$ 0.0187	$ 0.0093
Operating charges per annum..	$15 335	$11 064	$ 4 271
Fixed charges per annum......	$ 2 602	$ 1 604	$ 998
Total expense per annum.......	$17 937	$12 668	$ 5 269

The mere collecting of information, however, will not bring in the business. The results of the analysis must be presented to the manufacturer in a way that he will understand. He must understand it to believe it. This calls for salesmanship. In other words, neither engineering nor salesmanship are sufficient in themselves. The combination of engineering and salesmanship are necessary to procure the best results.

TABLE IX—RESULTS OF AN INVESTIGATION AT A BITUMINOUS COAL MINE

Item.	With Isolated plant.	With Central Station Service.	Saving through Central Station Service.
Consumption kw-hr per annum.	2 293 700	2 293 700	......
Cost per kw-hr................	$ 0.0248	$ 0.015	$ 0.0098
Total expense..................	$56 860	$37 212	$19 648

TABLE X—RESULTS OF AN INVESTIGATION AT SPRING MANUFACTURING PLANT

Item.	With Isolated plant.	With Central Station Service.	Saving through Central Station Service.
Output per annum.............	......	828 000	......
Cost per kw-hr................	$ 0.066	$ 0.013	$ 0.053
Operating charges per annum..	$22 000	$17 878	$ 4 122
Fixed charges per annum......	$ 6 512	$ 2 620	$ 3 892
Total expense per annum......	$28 512	$20 497	$ 8 014

This method of outlining the advantages accruing to manufacturers from the use of central station power has been found in actual practice to be very satisfactory, and power companies using this method are meeting with splendid success.

IMPROVEMENTS IN THE MANUFACTURE OF INCANDESCENT LAMPS

B. F. FISHER, Jr.

THE improvements in the quality of incandescent lamps have been of greater importance and the progress made in their manufacture has been more rapid during the year past than during any previous year. During this year the manufacture of tungsten filament lamps has been reduced from an art to almost an exact science. Tungsten wire can now be drawn in any reasonable lengths to approximately an exact size. The different processes of manufacture have been standardized so that the element of variation is almost eliminated. Designs have also become so standardized that lamps are much more uniform.

The possibility of getting wire of an exact size, and the standardization of the processes and designs make it possible to manufacture lamps for an exact voltage and efficiency. If it is desired to make a 40 watt lamp, at an efficiency of approximately 1.17 watts per candle at 115 volts, it is possible to select 40 watt size wire, cut it into the correct lengths for 115 volts and make lamps from these lengths of filament with a greater degree of accuracy and uniformity after seasoning than could possibly be secured by using the method of photometering the lamps in a well equipped commercial photometer room. This ability to make lamps to voltage and watts per candle will completely revolutionize the incandescent lamp business. With Mazda lamps it will be desirable to have all of the demand for lamps at a single voltage instead of the great spread in voltage formerly necessary for carbon and metallized filament lamps. This spread was necessary on these lamps to avoid an excessive demand for any one voltage. If all orders for Mazda lamps could be confined to 115 volts, or any other single voltage, it would simplify not only the Mazda lamp business but also the entire central station business in that all heating devices, motors, etc., could be wound for one voltage.

The possibility of getting wire of an exact size has made it possible to make each size of lamp from one size of wire for all voltages within reasonable limits, by simply changing the length of wire used to suit the voltage. Therefore, lamps made for multiple burning will work satisfactorily in series service without selecting for current, because the lamps will all be made of wire having the same diameter, and hence the same current capacity.

Photometry, at the speed necessary in commercial photometer rooms, is the least accurate of all of the processes involved in the manufacture of Mazda lamps, and must be entirely dependent on the judgment and accuracy of the operator in matching the screens and reading the instruments. The increased accuracy of manufacture, due to the use of single size wire, will probably make it unnecessary to photometer all lamps. The only photometry necessary will be to measure a limited percentage of the lamps to see that errors have not been made. After the exhausting operation, if a Mazda lamp is burned on a constant potential, there is a rapid increase in candle-power for the first few hours, the rate of increase diminishing rapidly until the peak has been reached in about fifty or sixty hours. Heretofore Mazda lamps have been seasoned or burned in manufacture until the rapid increase in candle-power was completed before lamps were photometered. To-day the possibility of making lamps accurately to voltage and watts per candle makes it unnecessary to season them. The lamps when exhausted will vary in candle-power over quite a wide range, but if they are operated on the voltage for which they were intended the candle-power of the different lamps will rapidly change, until, at the end of twenty or thirty hours burning, the candle-power of all lamps will be more uniform than was possible under the old method of photometering the lamps for volts, which measurement was to a great extent dependent on the judgment of the operator.

The drawn wire tungsten filament is very ductile and of great tensile strength before heating, and as it is possible to manufacture some sizes of Mazda lamps without passing current through the filament, in such lamps the filament is practically indestructible until the lamps are placed in service. The omission of the seasoning operation in manufacturing lamps thus preserves the strength of the filament, and prevents breakage in shipment and handling before the lamps are installed.

It has been generally known that any lamp would blacken in time, even if operated at its proper efficiency and if it did not break before the electrical burn-out point had been reached. The length of time a lamp would burn, after blackening had become so dense that it was objectionable, was often greatly in excess of the time the lamp burned before blackening became objectionable, and it has been the hope of the manufacturer to be able, either to prevent blackening entirely or delay its appearance until near the burn-out point of the lamp. In the carbon filament lamp the improvement in delaying blackening was made in the invention of the metallizing processes. This delayed the appearance of blackening to such an extent that the efficiency of the lamp was increased to 2.5 watts per candle with approximately the same or longer hours of life before the appearance of objectionable blackening than was possible with the ordinary carbon filament lamp at 3.1 watts per candle. Similarly, in the Mazda lamp during the past year improvements have been made which delay the appearance of blackening or prevent it entirely until the ultimate or burn-out life has been approximately reached. These improvements make available for satisfactory use a much greater percentage of the total life and make it possible to increase the efficiencies of Mazda lamps without shortening the life, to the appearance of objectionable blackening. In the lamps of larger size these increases have been radical. The 250 watt and higher wattage lamps now operate satisfactorily at efficiencies in excess of one candle per watt, and the smaller wattage lamps down to the 60 watt size are approaching efficiencies of one candle per watt.

The success in making 40 and 60 watt lamps in smaller bulbs has been another radical improvement. The bulb formerly used on the 40 watt lamp was just too large to permit of the substitution of the 40 watt lamp for a 50 watt metallized filament lamp or a 60 watt carbon filament lamp, but during the year it has been found possible to make a satisfactory 40 watt lamp in the same bulb that is used for the 25 watt lamp, thus making it possible to take advantage of the benefits of the increased illumination or improved artistic effect from Mazda lamps without the necessity of changing fixtures. Similarly, the 60 watt lamp can now be satisfactorily made in the bulb formerly used on the 40 watt lamp, thus giving a lamp of higher candle-power which can be used in present fixtures without radical changes. These two improvements fill a want which has long been felt and had become insistent.

It is possible to wind drawn tungsten wire into close cylindrical coils of small diameter. In this manner long lengths of wire can be wound into small compass and this fact has made possible a complete line of candelabra lamps in decorative bulbs; also a line of lamps in which the filament is concentrated into a very small area for stereopticon or other focusing work.

There have also been many small improvements accomplished by standardizing the design of lamps. These improvements tend to better the performance obtained and widen the use of Mazda lamps, and they are now satisfactorily used in virtually every class of service in which incandescent electric lamps can be used. The increased popularity and the increase in the demand for Mazda lamps can be judged from the fact that the number sold in 1912 was 167 percent of the sales in 1911. The number of Mazda lamps sold in 1912 was also in excess of the number of lamps of any other one class, carbon, metallized filament or tantalum sold during that year and from present indications the sale of Mazda lamps during 1913 will nearly equal the total sales of all other incandescent lamps.

INCREASED EFFICIENCIES OF MAZDA LAMPS

J. FRANKLIN MEYER

DURING the few years that tungsten filament lamps have been on the market a considerable number of changes in their efficiency, i. e., watts per candle, have been made. The earliest lamps were rated at about 1.50 watts per candle, while to-day Mazda lamps are regularly rated at from 1.17 down to 1.00 watts per candle, and even lower. The carbon filament lamp has been sold for more than thirty years, yet the efficiency of carbon lamps remains practically the same that it was in 1884. A test made under the auspices of the Franklin Institute in 1884 on carbon filament lamps of five different manufacturers showed an average of 3.16 watts per candle. Carbon filament lamps manufactured to-day are rated at from 4.00 to 2.97 watts per candle, thus showing that very little change in the efficiency of the carbon filament lamps has been made. It is evident, therefore, that very much larger changes in the efficiency of Mazda lamps have been made during the few years that these lamps have been on the market, than have been made in the efficiency of carbon filament lamps in the whole history of the incandescent lamp industry.

In considering these large changes in the efficiency of Mazda lamps, it must always be borne in mind that an incandescent lamp, unlike most electrical apparatus, is not of fixed capacity as a converter of electrical energy. Take for example, a Mazda lamp labelled 25 watts, 115 volts. There is in such a lamp a definite length of tungsten wire, which at a given temperature has a definite resistance. An increase in the temperature of the filament increases its resistance, and by increasing the voltage applied to the terminals of the lamp, the wattage consumption is increased or decreased. The lamp in question is called a 25 watt, 115 volt lamp because when operated at 115 volts its energy consumption is 25 watts, and at the same time it is giving 21.4 mean horizontal candle-power. The lamp is therefore operating at an efficiency of 1.17 watts per candle (25 ÷ 21.4 = 1.17). But a lamp labelled 20 watts, 100 volts, would also consume 25 watts if operated at 115 volts. The candle-power of this lamp would, however, be 26.2 mean horizontal and it would operate at an efficiency of about 0.96 watts per candle. Now why is the first lamp called a 25 watt, 115 volt lamp, but not the second? Each lamp consumes 25 watts at 115 volts, but only one is labelled 25 watts, 115 volts. The reason the second lamp is not labelled 25 watt, 115 volts is that the efficiency, at which it would operate at 115 volts, is such that the life of the lamp would be shorter than good practice to-day demands.

TABLE I

Nominal Watts	Watts Per Mean Horizontal C-P
15	1.31
20	1.25
25	1.17
40	1.17
60	1.12
100	1.08
500	1.00

The example given above shows the necessity for the establishment of what are called *normal conditions* of operation for incandescent lamps. The volume of a certain mass of gas depends on its temperature and pressure, and the volumes of gases are always reduced to *normal conditions* of temperature and pressure, that is ° degrees C and 760 millimeters of mercury, when definite comparisons are made. In a similar manner the normal wattage and voltage of an incandescent lamp, as fixed by the manufacturer's label, are dependent on certain normal conditions that have been agreed upon. The watts per candle at which a lamp operates and gives a commercially satisfactory life is this *normal condition.* Table I gives the present watts per candle for some of the common types of Mazda lamps.

The candle-power of an incandescent lamp depends on the temperature of its filament, the higher the temperature the higher the candle-power. Now the higher the temperature at which a filament in a lamp is operated, the smaller is the number expressing its efficiency in watts per candle and the more efficient the lamp is said to be. The life of a lamp to burn out, or to a definite decrease in candle-power, is also a function of the temperature of the filament. The lower the temperature of the filament the longer the life or, in other words, the larger the watts per candle the longer the life, all the other conditions remaining the same. But here is precisely the reason efficiencies in Mazda lamps have continually and rapidly been decreased in numerical value. The great improvements that are being made in manufacturing operations have been of such a character as to make it possible to operate Mazda lamps at higher and higher temperatures *with no decrease in life.* As a result of these improvements the efficiency of the 25 watt Mazda lamp has, for example, been continually decreased from 1.50 watts per candle in 1908 to 1.17 watts per candle in 1913, while lamps of certain higher wattages have been decreased to 1.00 watt per candle, all the changes having been made without decrease in life of the lamps.

As a result of these changes in efficiencies, the user has been continually receiving lamps of higher candle-power for the same power consumption. Since prices have also decreased very much, and lamps are longer lived than ever before under ordinary conditions of use, users have been greatly benefited. Tungsten filament lamps as first made were extremely fragile and liable to break or burn out. Lamps as now manufactured are very much more rugged in construction and, at much better efficiencies, give actually longer service than lamps at lower efficiencies as formerly made.

Mazda lamps have changed more in efficiency in five years than carbon filament lamps have changed in thirty years. The changes in efficiencies that have periodically been made have not decreased the life of lamps, the life of lamps in service at present day efficiencies being actually longer than ever before. Changes have been made only as the results of improved methods of manufacture, and in no case has the life of lamps been decreased by such changes. These changes in efficiency have continually given the user lamps that produce more light for the same power consumption.

INTERESTING FACTS CONCERNING THE HORN GAP

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National Properties Company, New York and Pittsburgh

THE history of the horn gap may be said to date from March 4th, 1896, when the Italian government issued to Ernest Gustav Paul Oelschlager and Karl Otto Franz Schrottke, Patent No. 40 698, assigned to Siemens & Halske Electric Company, of Germany. On August 18, 1896, the U. S. Patent Office issued to these same inventors Patent No. 566 011, which was assigned to the Siemens & Halske Electric Company of America. The construction of this horn gap, Fig. 1, and its use as a lightning arrester, are generally known. The theory of a Siemens horn gap lightning arrester as set forth in the patent specifications is as follows:

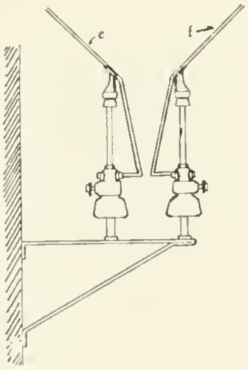


FIG. 1

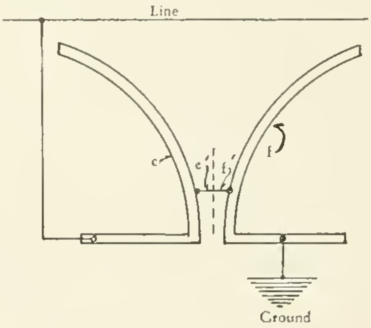


FIG. 2

When the arc is established, as at c' f', Fig. 2, the surrounding air is rapidly heated, causing an upward current of air at that point, which tends to carry the arc with it. In addition to this it is well known that conductors under the influence of an electric current tend to arrange themselves in parallel positions. The arc c' f' being practically at right angles with the uprights, the portion c' tends to assume the position of the upright c and coacts with the upward current of air in lifting the arc, as indicated in Fig. 2. Similarly the portion f' tends to assume the position of upright f. Thus any arc which may be formed between the uprights is quickly raised to the divergent portions of the uprights and thereby becomes self-extinguishing, the thermo-dynamic and the electro-dynamic forces coacting to drive the arc upward and extinguish it.

By investigating records at the patent office, it was found that there have been several attempts by inventors to improve the horn gap, and that patents have been granted on improvements. It is a curious fact that the American manufacturers, to whom these patents have been assigned, for many years made no effort to place them on the market. When they found it necessary to use a horn gap in connection with the electrolytic lightning arrester, it is interesting to note the horn gap used is of the Siemens type, and not of an improved type, which indicates that the improvements were not completed.

It is interesting to note the different methods used by inventors to increase the efficiency of the horn gap. The following is a brief description of some of the more important types:

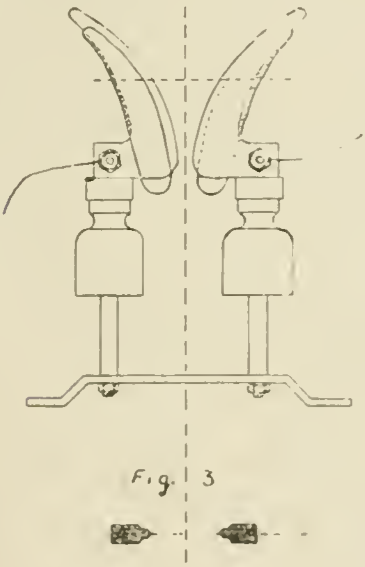


FIG. 3

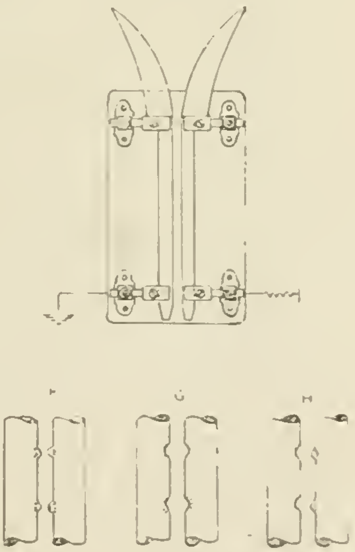
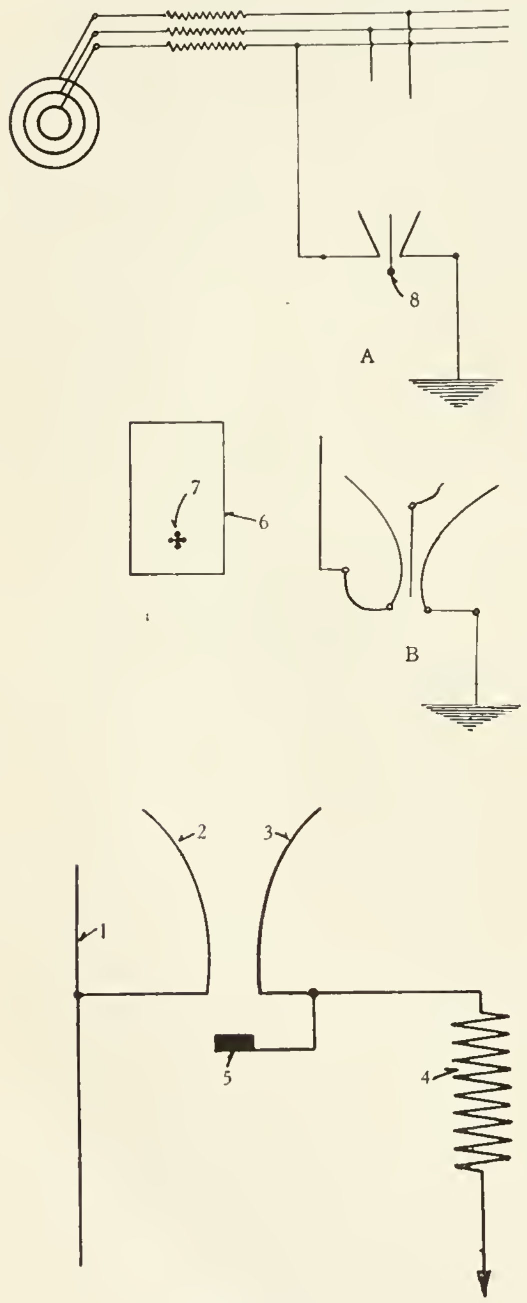


FIG. 4

Fig. 3 illustrates an improved horn gap covered by U. S. Patent 701 577, dated June 3d, 1902, issued to F. E. Klein, of Dresden, Germany. In the specification, the inventor points out that in a Siemens horn the arc is slow in rising on the horns due to insufficient magnetic field, and that by inserting an iron sheath, the magnetic field is increased, and that an arc formed on horns provided with this sheath will rise on the horns and be extinguished much more quickly.

Fig. 4 illustrates an improved horn gap invented by F. Jordan, covered by U. S. Patent 807 277, dated December 12th, 1905. This patent was assigned to the Elektrizitats-Aktien-Gesellschaft vorm W. Lahmeyer & Company, of Frankfort-on-Main, Germany. In the specifications, the inventor aims to improve the horn gap by preventing beads of fused metal from forming, thus lessening the arcing gap and changing the calibration of the arrester. The invention is illustrated in Fig. 4 at *F, G* and *H*. *F* relates to a horn gap in which both electrodes are of metal. Beads of fused metal are formed at the points between which the spark jumps, and the space between the electrodes is reduced. At *G* the electrodes are composed of carbon. In this case the distance between electrodes is increased by the depression formed by a spark between them. At *H,* which illustrates the invention, is shown the combination of an electrode of metal with an electrode of carbon. To the formation of molten metal on the metal electrode corresponds a depression on the carbon electrode, so that the distance of air-gap of the electrodes remains the same along their whole length.

In Fig. 5 is shown an improved horn gap scheme, invented by John Pearson, of Somerset, Wis., U. S. Patent No. 887 221, dated May 12, 1908. In carrying out his invention the inventor provided a horn lightning arrester with a barrier which is insulated, the object being to break the arc so that it will extinguish quickly. The inventor shows two ways, *A* and *B,* of accomplishing this, and describes them as follows:



FIGS. 5 AND 6

The barrier, which is provided in accordance with the invention, is preferable in the form of a thin plate *6*, which, as illustrated in the drawings, may be assumed to be a sheet of mica, having, as shown, near its lower portion, one or more small perforations *7* in line, or approximately in line, with the most closely positioned portions of the two horns of said arrester. This barrier may be held in the position stated, by a slit supported pin *8*, or by any other suitable form of holder. With the barrier interposed between the horns of the arrester, as shown at *A*, a lightning charge from the line being of enormously high voltage and of very small quantity or amperage will force its way through the perforations *7* of the barrier, while with the arrangement shown at *B*, the lightning charge will force its way from one horn to the other under the barrier. Otherwise stated, the barrier offers resistance to the passage of the dynamic current, and on account of thermal and electrodynamic action it flashes upward or around the barrier, generating great heat and causing the heated gases to rush upward and to carry or force the dynamic arc up to the upper ends of the horns of the arrester, where the resistance through the air, from the one horn to the other, becomes so great that the arc goes out.

Fig. 6 illustrates an improved horn gap invented by R. Apt, covered by U. S. Patent 855 440, dated June 4, 1897, and assigned to the General Electric Company, of New York. The operation is described as follows:

At operating potentials up to about 3 000 volts, difficulty arises from the fact that the spark gaps must be very small in order that they may act with sufficient sensitiveness at a potential exceeding the normal potential of the system. Such small sparking lengths, however, entail disturbances of various kinds. Small impurities may alter the proper relative distance of the electrodes to a considerable extent, and bridges may easily form across the gap by dirt, rain drops or insects, and may thereby break down the spark gap and cause disturbances in operation. The present invention utilizes the property of the so-called radio-active substances to reduce the sparking potential so that a spark gap is produced which possesses considerable length, even at small potentials. The general plan for carrying out this idea is shown diagrammatically in the drawing, forming a part of this specification. In the drawing, Fig. 6, the line conductor *1* to be protected, is connected to an electrode *2* of a spark gap, and the corresponding electrode *3* is connected to ground through resistance *4*. A body of radio-active material *5* is supported in a small receptacle in proximity to the spark gap in such position that radiations therefrom will pass into the space between the sparking electrodes *2* and *3*. Radiations from this source act upon the spark gap or sparking members by ionization in such manner that a potential of a given value can pass through a considerably longer air-gap than would otherwise be the case. As the effectiveness of the radio-active substance does not change or weaken within a reasonable time, this source of radiation requires no attention and may be regarded as practically constant.

There are several other patents, all of which aim to increase the efficiency of the horn gap, but are more or less improvements on one of the above mentioned. A review of the above facts would indicate that there are two principal defects with the horn gap:

1—When the gap is broken down, the lightning discharge is followed by the line current, which continues to flow across the gap to ground until the arc is lengthened sufficiently to limit and extinguish this flow of current. The cause of this is traceable to the slowness of the arc in rising on the horns. The usual method of overcoming this defect has been to insert resistance in the ground lead, thus limiting the current to an amount which would not cause a disturbance on the line. Some inventors have endeavored to correct this by increasing the magnetic field induced by the arc, thus causing the arc to rise more rapidly on the horns, and it is evident that if this could be successfully accomplished, there would be no necessity for inserting resistance in the ground lead, as the arc would insert its own resistance and be extinguished before it could cause any serious disturbance.

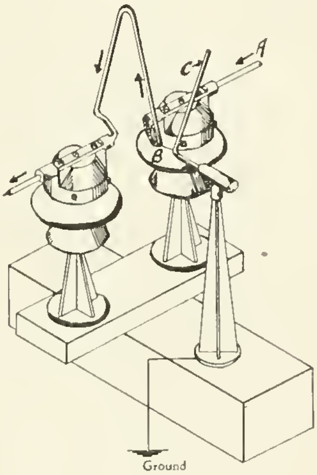


FIG. 7

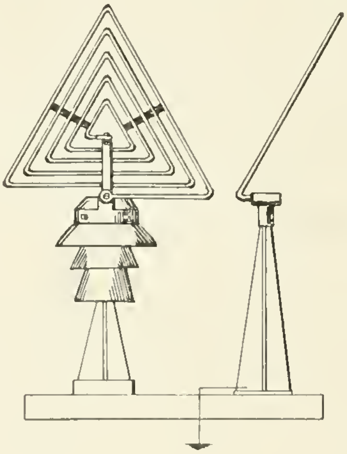


FIG. 8

2—The Siemens horn gap, as constructed, requires a close setting of the air-gap, and a small variation makes a considerable difference in its effectiveness as an arrester. If the gap be widened too much, the arrester soon becomes ineffective. This point has been seriously considered by inventors, and some of the methods of overcoming this defect have been set forth in patents as described above.

An interesting improved horn gap, which has recently been placed on the market, aims to overcome all of the above defects in a very simple and effective manner. This is illustrated in Figs. 7, 8, 9, 10, 11, 12 and 13. In Fig. 7 is illustrated a single loop series horn gap. In this case there has been a radical change in the method of using the horn gap. Whereas previous horn gaps have been connected *in shunt* with the line, this device is connected *in series* with the line, and all the working current flowing in the line also flows around the horn, the horn also acting as an effective choke coil. This device is so constructed that a sharp bend is made in the line at the arcing point, and it is evident that current flowing in the line will meet its first obstruction at this point, and the potential stresses will be built up at this point, and consequently have a maximum tendency to jump the gap. It is claimed that with this construction the accurate setting of the air-gap is no longer of prime importance, as an arrester of this construction can have an air-gap 50 percent greater, and still be more sensitive than an arrester of the old type, thus allowing a larger air-gap to be used, and enabling this type of arrester to operate successfully on as low a voltage as 2 200 volts. It is further claimed that this arrester is very effective in relieving static from the line. It is also very evident that with this construction, the magnetic field will be increased by the amount of working current which is flowing around the horn, and it is claimed that on low voltage lines carrying 25 amperes and above, this additional increase in the electro-dynamic field is sufficient to allow the arrester to operate without any resistance in the ground lead, the arc rising and lengthening on the horns so rapidly that sufficient resistance is almost instantly interposed, and the current limited in this manner.

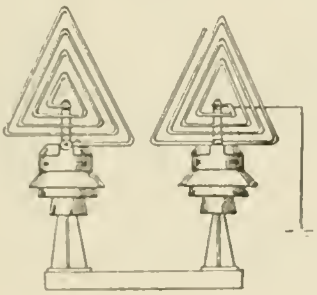


FIG. 9

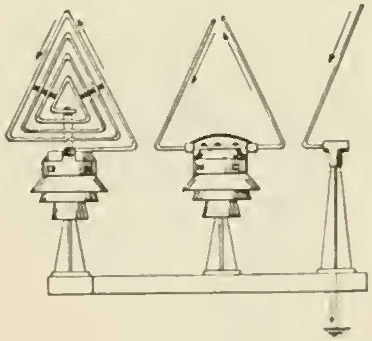


FIG. 10

In Fig. 8 is shown a development of this construction, whereby a series of five turns are used, thus increasing the choke coil effect and the electro-dynamic field to such an extent that it is claimed that this arrester will operate successfully with very little current flowing in the line with voltages up to 45 000 volts, without any limiting resistance connected between it and the ground.

In Fig. 9 is illustrated a still further development of these same principles. In this case a spiral reactance is placed in the ground lead. This at first appears to be a bad arrangement, as it is generally considered bad practice to place a choke coil in a ground lead of any lightning arrester; nevertheless, to offset this, it is claimed that, where a very efficient horn gap is desired, this arrangement has proved very effective. The ohmic resistance of this reactance being exceedingly low, there will be little opposition to the discharge of static, but when an alternating or line current attempts to follow, the reactance element becomes effective and limits the amount of current which can flow, and also greatly increases the electro-dynamic field, causing the arc to rise on the horns very rapidly. This type of arrester is recommended for protecting lines where a very effective arrester is required and where there is not a large amount of current flowing in the line, or where the transmission line or substation is out of service part of the time. With this construction, the magnetic blowout effect caused by the lightning discharging through the grounded reactance, is sufficient to make the arrester operate without causing a disturbance on the line.

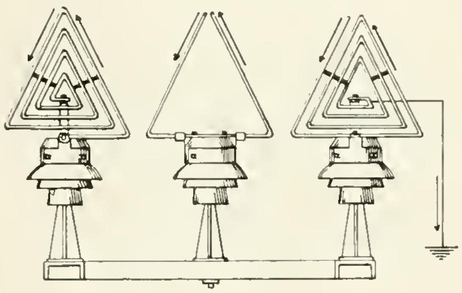


FIG. 11

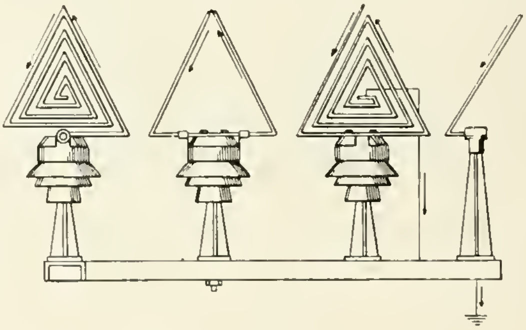


FIG. 12

Arrows indicate instantaneous direction of current.

In Figs. 10 and 11 are shown still another development of this principle. It is claimed that on high voltages, such as 66 000 and 88 000 volts, where horn gaps are used, the height of a horn is so great that it takes considerable time for the arc to rise and lengthen sufficiently to break, during which time there is a rush of current to ground, which usually causes disturbances on the line. The object of this construction is to break the arc into two parts, so as to obtain the same maximum breaking distance in less time. It is claimed that with this construction, the time required to break an arc is only 30 percent of that required by the common type of horn-gap.

In Fig. 12 is illustrated the final development of this type of arrester. This differs from Fig. 11 in that a third gap is provided, which is shunted around the grounded reactance and acts as a relief gap. If a very heavy high frequency discharge breaks down the gaps, and the reactance offers too much opposition to the discharge, the third gap will be broken down, giving a direct flow to ground until the current is reduced, when the third gap will break, leaving the discharge to pass through the two gaps and the reactance. The operation of the third gap is very similar to a shunted gap arrester. In Fig. 13 is shown diagrammatically the direction of current through the arrester.

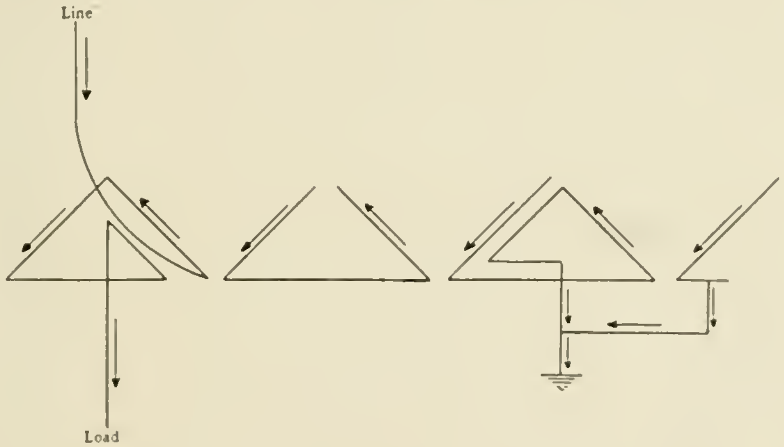


FIG. 13

Horn gap arresters built on the above principles have been in successful operation for the past three years and are finding favor throughout the country. They operate successfully without causing a disturbance on the line; they will successfully dissipate an arc before the circuit breakers at the power-house can open; they require no attention; can be mounted outdoors, and will operate successfully in all kinds of weather.

THE STREET LIGHTING AND FIXTURES OF THE CITY OF NEW YORK

ITS PLAN OF DEVELOPMENT AND PRESENT CONDITION

C. F. LACOMBE,
Chief Engineer, Department of Water Supply, Gas and Electricity, New York City

THE street lighting of the City of New York, to the average citizen, is one of those simple, obvious matters of daily life that is always with him, and is taken as a natural phenomenon like daylight. It is only when it is very inferior and he cannot see sufficiently well, that he notices it, and then, of course, to complain. As a matter of fact, however, since the birth of electricity, street lighting has grown into an art, as well as an exact science. This is said advisedly, for successful lighting is a combination of both. Without artistic treatment, it is not attractive, and without scientific study it is not economical. It has been said many times that street lighting developed first as a police function, and that this function is its most important one. Mr. Roosevelt, when a police commissioner, is credited with the remark that "an arc light is equal to a policeman." That is probably so, but the lighting of the city has now progressed far beyond the police requirements of his day. Street lighting is undoubtedly a great aid to policing the city, but the lighting that has served for that purpose is no longer satisfactory. In older days, even in this city, the night life was comparatively short; people out after twelve or one generally gave an excuse for it. Today, after the theatre comes the supper, the cabaret show, dances until breakfast, etc. The night workers who produce all the things demanded by the present prodigals, are thousands in number, and the streets in Manhattan Island are now lighted not only for the police, but for the general use of the people who wish to be amused, and the people who have to work to amuse them.

To contrast the old and the new conditions, it may be noted that the amusement center of today, thirty years ago was known as Longacre Square, rarely seen, lighted by open flame gas lamps and occupied by cheap little stores and grubby boarding houses. It seems that the present congested condition in Manhattan justifies the statement that the day requiring only police lighting is past, the day of real street illumination for great and general use through the night has arrived, and any system of street lighting that does not fill this requirement is insufficient.

Further, this has been due, without any question, to the impulse given by electric lighting and the scientific and artistic advance of illumination by electricity. Photographs of the old, the present and the coming street lighting are shown by the illustrations accompanying this article.

In order to make the lighting situation in this city clear, it is necessary to describe briefly the limitations under which one has to work in the city government. Like all artistic or utilitarian things, illumination is a matter of money to a certain degree. Since 1905, the Legislature has limited properly the prices to be paid for illuminating units, and the Board of Estimate and Apportionment, in the budget, has limited from year to year the number of units of illumination that may be added by setting the amounts of money that can be used in each borough. There are further limitations in connection with opening streets, etc., which restrict the time of construction, particularly in Manhattan and Brooklyn, so that only a certain amount of physical work can be done each year. In consequence, progress in improving lighting is slow and conservative, to avoid frequent changes, and should be so, particularly in the older sections of the city. New units are not adopted without careful study and trial, and in this term units, is included both the light source, its reflectors and diffusing media. From this you can see that we are limited to the use of standard tried lighting units, as the illumination purchased by this city must not be affected to its detriment.

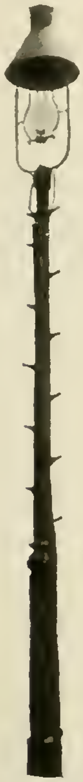


FIG. 1—OLD FASHIONED UGLY CAST IRON POST

Used with open series arc lamp in the early electric lighting days.

The city contracts with public service corporations to supply it with certain illumination and illumination service on its streets. This means that the illumination is to be given by certain proved lighting appliances, or in other words, proved units, and these appliances or units are to be kept in a condition giving as nearly as possible perfect operation. The term "perfect operation" is the definition of "good service." It depends on many elements and great attention to detail. Good service in electric, and largely in gas lighting, depends on the operating and reserve capacity of the central station and its relays, the perfection and reliability of the distribution system, the detailed care and attention given to the most reliable lighting appliances obtainable for the system, and last, but not least, the discipline, coördination and coöperation enforced between the above elements as established and maintained by the man in charge. This man and his loyal assistants may really be called the slaves of the lamp, and those of us who have been such slaves, know the strange fascination of this work and its demand for the sacrifice of all else to it. But that fascination and devotion mean good service, and you can never get successful lighting service without it. Nor can you get that steady, continuous illumination without which any attempt towards agreeable or artistic lighting is futile. Good service is rare, but rare is coöperation be-

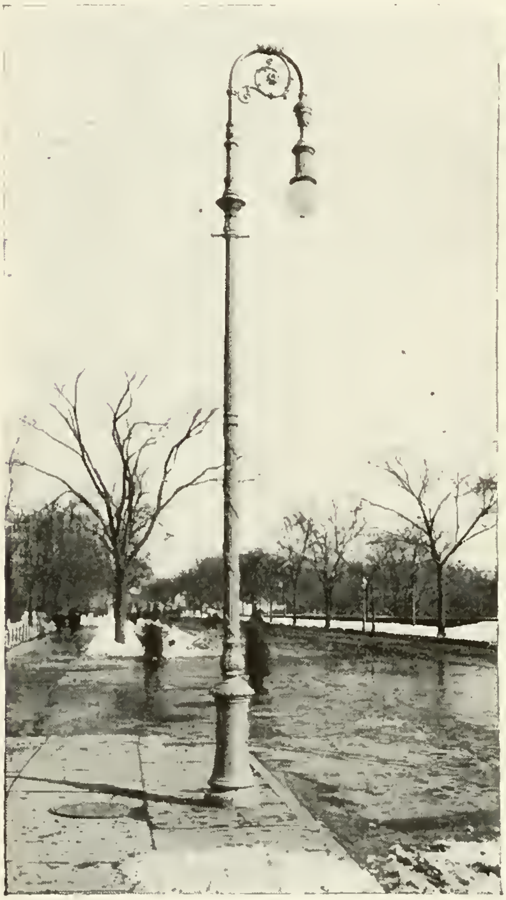


FIG. 2

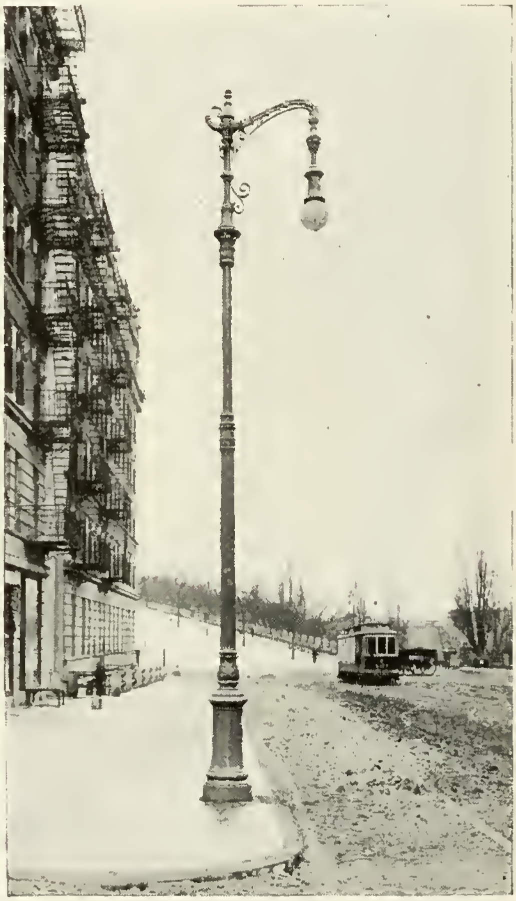


FIG. 3

FIG. 2—BISHOP CROOK POST

These posts have no lowering device, and the lamp is recarboned from the post or by a tower wagon.

FIG. 3—REVERSE SCROLL BRACKET POST

Ornamental, and as effective in illumination as the Bishop Crook post if not more so, on account of the additional height of the lamp.

tween the city and the contracting company. This, on the city's part, means strictly fair, semi-judicial engineering supervision, without any political bias. The city must watch jealously its own interests through experienced and unbiased engineers, and insist on the observance of simple business rules, such as a steadily decreasing price for a steadily increasing use of standard units.

On the company's part, this coöperation requires a marked civic pride, an ambition to make its equipment and service the best possible within its means, and a broad policy of development encouraging increases of future additional business. Examples of both are rare indeed in this country, but a few shining examples do exist. Assuming these conditions to be obtained,

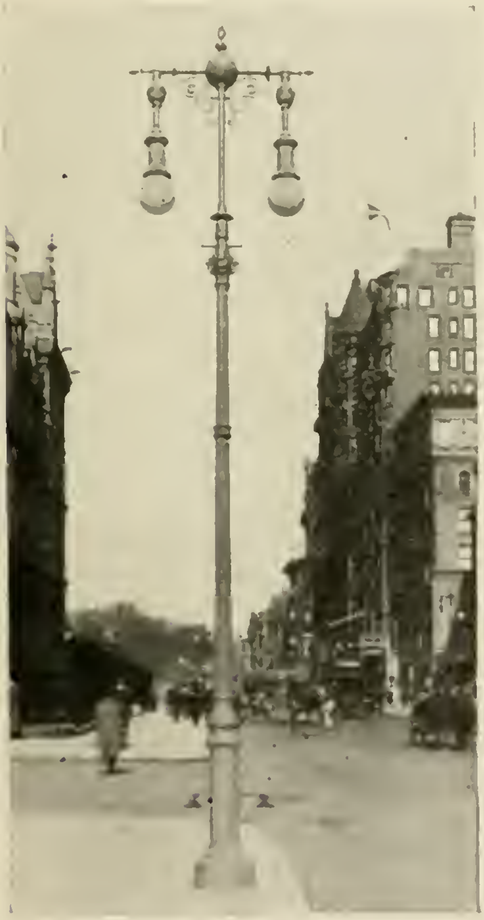


FIG. 4

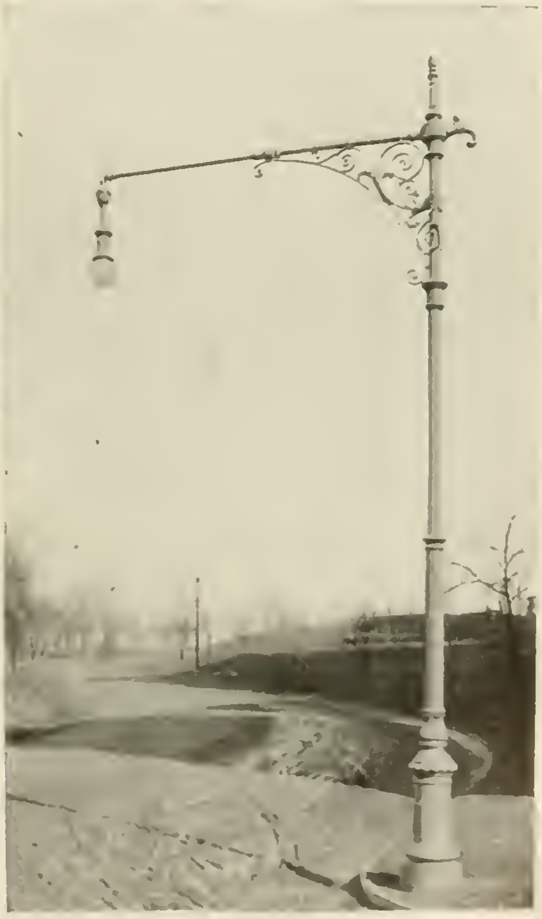


FIG. 5

FIG. 4—TWIN LAMP POST

This post has been lengthened beyond its original height, and is equipped with two 450 watt enclosed carbon arc lamps.

FIG. 5—MAST ARM POST

The mast arms get the lamp away from tree interference. The arm is of steel and the ornamental sleeves are slipped over the steel posts then, let us see what choice is given us as to the lighting appliances to be used. It is apparent on a moment's thought, that, as stated, such appliances must be well tried and standard. New appliances cannot be used on regular service. They must be given long service tests in by-ways and unimportant sections, often improved and retired until they become reliable and of real value. Of such available appliances today, we have the arc lamp of standard design for both types of current supply, and for both multiple and series systems; the incandescent lamp, in various intensities, of the carbon, metallized and metal filament types, for similar current supply and distribution systems; the mantle gas lamp with either vertical or inverted mantles, increasing in number of mantles for increasing illumination, and further, naphtha mantle lamps, giving the same illuminating effect as vertical mantle gas lamps. In addition, but not available in all parts of the city, are the high candle-power arc lamps using a metallic electrode, with which much can be done. In Manhattan, where the greatest congestion exists, we are now trying long burning white flaming arc lamps, giving still higher illumination for general street lighting, by installing a limited number on Broadway, above Forty-seventh street, and on Seventh avenue, above Thirty-fourth street. This list of lamps, then, comprises our lighting units, and they are the tools with which we must work at present.

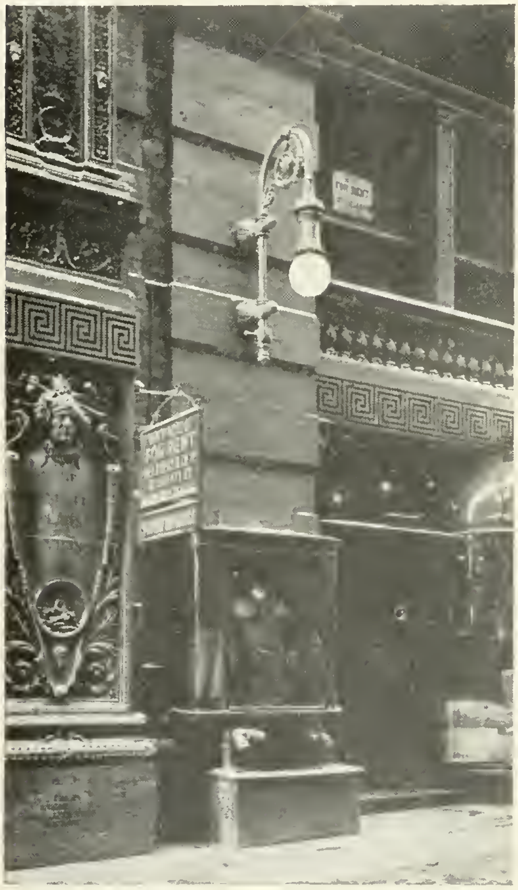


FIG. 6—LAMP BRACKET

For use on buildings in narrow streets, where a post would take a material width of the limited sidewalk.

This city differs from others in that we have two systems of street lighting, one low tension, direct and alternating-current multiple in the Borough of Manhattan and part of Brooklyn, whereas in all the other boroughs, and in by far the larger part of Brooklyn, the street lighting is by means of comparatively high tension direct and alternating-series systems, with a few minor exceptions. Gas supply for mantle lighting is available throughout the greater city, except in a few remote sections. Naphtha mantle lamps are still used for frontier lighting, where neither gas nor electricity is available. It was formerly used in parks, but is now being abandoned for obvious reasons, in favor of the tungsten incandescent lamps. Of these various units, in the greater city, there are:

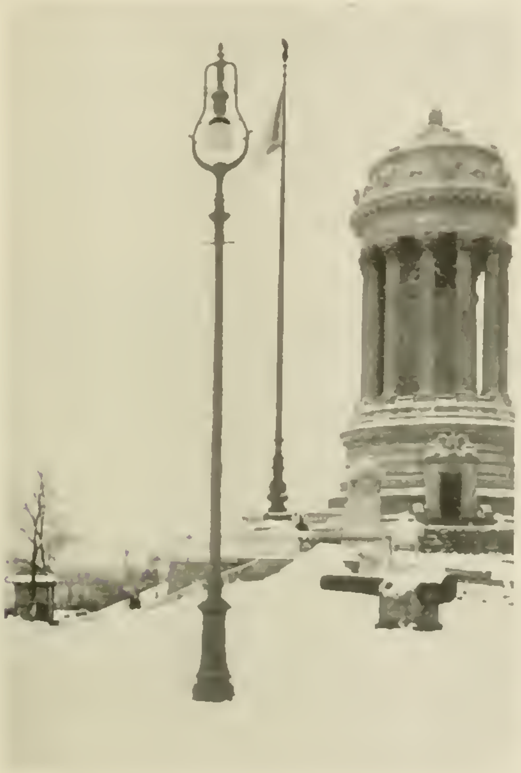


FIG. 7

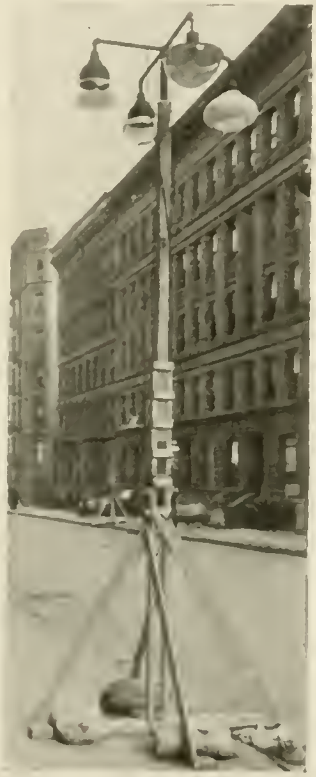


FIG. 8

FIG. 7—LYRE TOP POST

Used in parks, and in center parked plots on broad streets.

FIG. 8—EXPERIMENTAL POST

The lamps must be taken into the streets to secure the final effect; work in the laboratories is not enough. The posts are adjustable as to position and height, and are equipped with four lamps, each with a different type of reflector.

10 180 arc lamps.
17 991 incandescent lamps.
78 flaming lamps, permanent and on trial.
14 063 single mantle gas lamps.
28 inverted mantle gas lamps on trial.
1 816 naphtha vapor lamps—a total of 83 746 lamps of all types.

Expressed empirically and approximately, in terms of horizontal illumination, these lamps give an illumination equivalent to fifteen million candles, and are furnished by twenty-eight lighting companies. For the purpose of street illumination, these lamps are used in the following manner:

Arc lamps, reinforced by flaming arc lamps, at points of great congestion, as at Times Square, Manhattan.

Arc lamps on main avenues and business streets, practically over their whole length in Manhattan, and as far as necessary in other boroughs, and then merged into tungsten incandescent electric or gas mantle lamps.

Gas lamps are generally used in the residence districts and on unimportant streets, little used at night, although of late, for many reasons, the tungsten lamp has made great inroads on this territory.

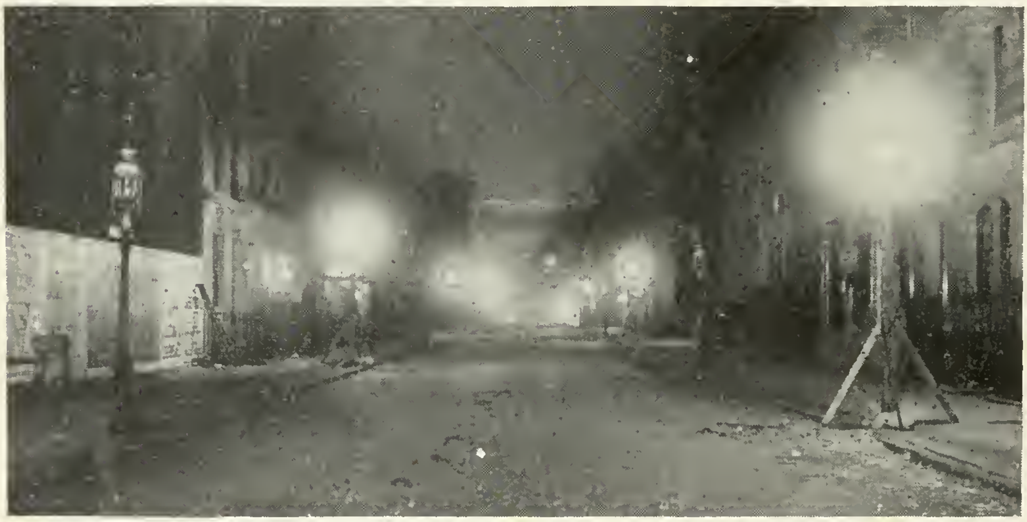


FIG. 9—NIGHT VIEW OF STREET LIGHTED BY LAMPS ON EXPERIMENTAL POSTS

Ten years ago last month, when the supervision of the illumination of Manhattan and the Bronx was put in the charge of an engineer, it was found to be inadequate, unsymmetrical and out of date, the arc lamps on the main avenues were insufficient and often placed irregularly, too far apart and not in symmetry in line or in height, except where standard fixtures were employed. Open flame gas lamps were in the majority, with mantle gas and arc lamps often mixed in with them. In other words, there was little, if any, system of lighting. As soon as possible, this was corrected; first, prices were materially reduced by continuous agitation, and second, a plan of lighting developed. All open flame gas lamps were discontinued. Arc lamps were practically doubled in number at street and avenue intersections, and symmetrically arranged as often as possible on street house lines, so that the illumination was made as uniform as it could be with the funds available. Mantle gas lamps were put on existing lamp posts on all residence streets, where arc lighting did not exist, as it did in a few quarters. This system as a whole has proved efficient and has been followed with improvements as they are worked out. The result is shown in the uniform increased system of distribution of light sources in long straight parallel lines, exemplified best, first by Seventh avenue, above Central Park, and Fifth avenue, from Washington square to Sixtieth street, and now by almost all the avenues in Manhattan, from West to East, running North and South, as well as on the main streets running East and West.

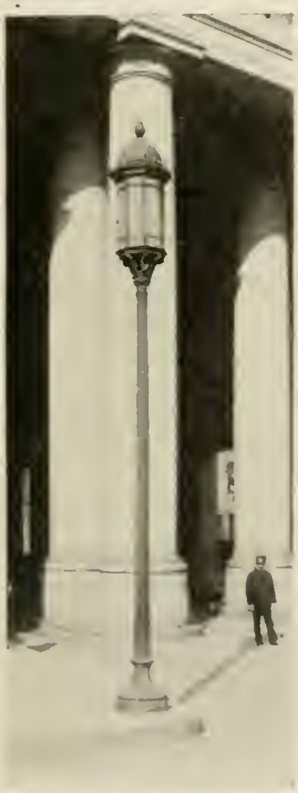


FIG. 10

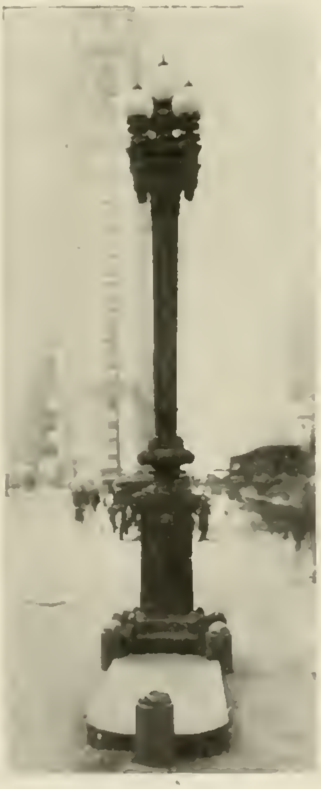


FIG. 11

FIG. 10—TYPE OF POST AND LANTERN USED AROUND PENNSYLVANIA STATION

This is a high post and is used with heavy diffusing glassware for Nernst or high power tungsten lamps.

FIG. 11—TUNGSTEN ILLUMINATION AT ISLE OF SAFETY, TIMES SQUARE

Late in 1905, the engineering charge of the illumination of the Greater City was put under one man as chief engineer, and early in 1906 such control was formally assumed. The same general system as used in Manhattan and the Bronx was put in effect in the other boroughs, and the bureau organization in these boroughs made to conform to the simple system of development in illumination just described in Manhattan. It was modified in some ways, for in the outlying sections of Brooklyn and in Queens and Richmond the problem was quite different. In these boroughs it was the illumination of small towns and centers, with long connecting roads through truck farming districts from center to center. These districts are lighted by means of far flung alternating and direct-current series systems of electrical distribution overhead on poles, with all the limitations of such suburban systems and companies. The

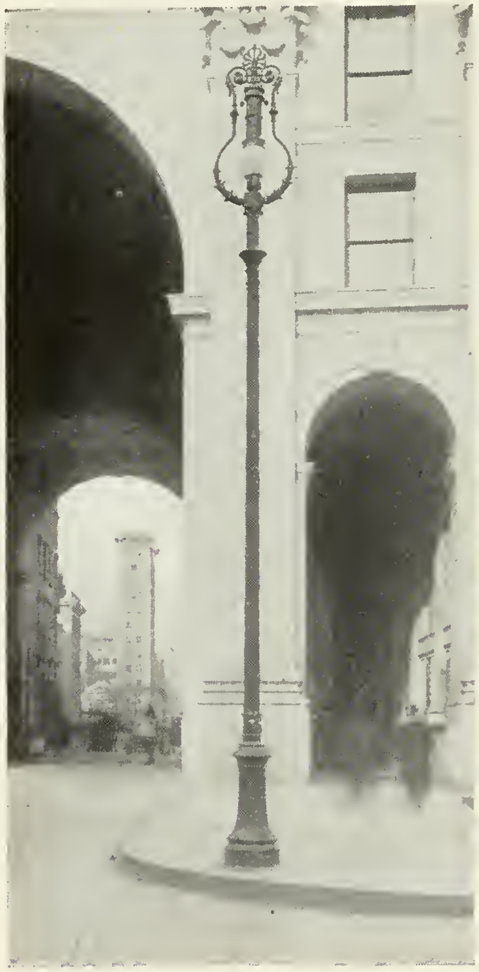


FIG. 12

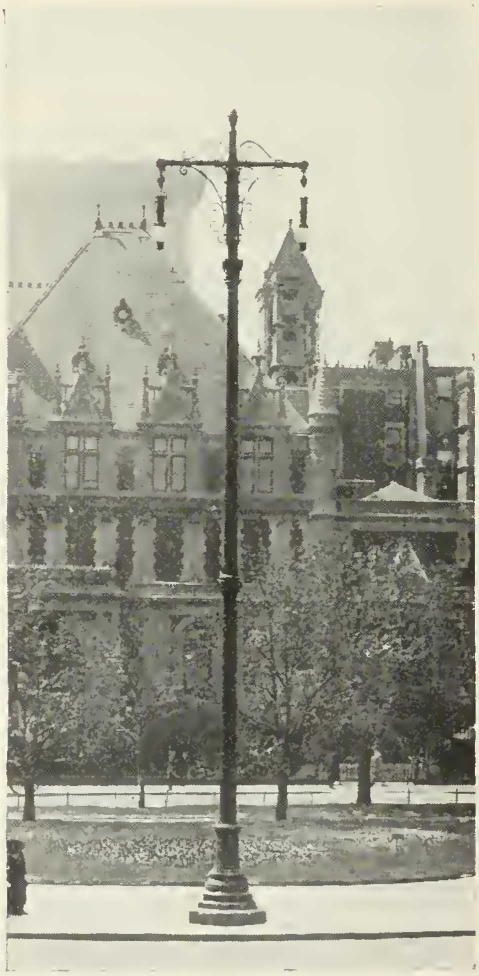


FIG. 13

FIG. 12—TYPE OF POSTS USED FOR FLAMING ARC LAMPS

Surrounding the new Municipal Building. This building is expected to be the center of great congestion. Hence, a powerful lighting is desirable

FIG. 13—HIGH TWIN POSTS AND FLAME ARC LAMPS IN SQUARES AND OPEN PLACES

Supplementing standard and inverted arcs and tungsten post lighting. These high powered lamps are located on prominent squares and corners where considerable congestion requires exceptional illumination. The lamps are located about 40 feet above the sidewalk and take 12 amperes per pair.

same rule was worked out in symmetrical, continuous and uniform illumination with arc and tungsten lamps, and there are now established certain lines of well lighted roads from the City

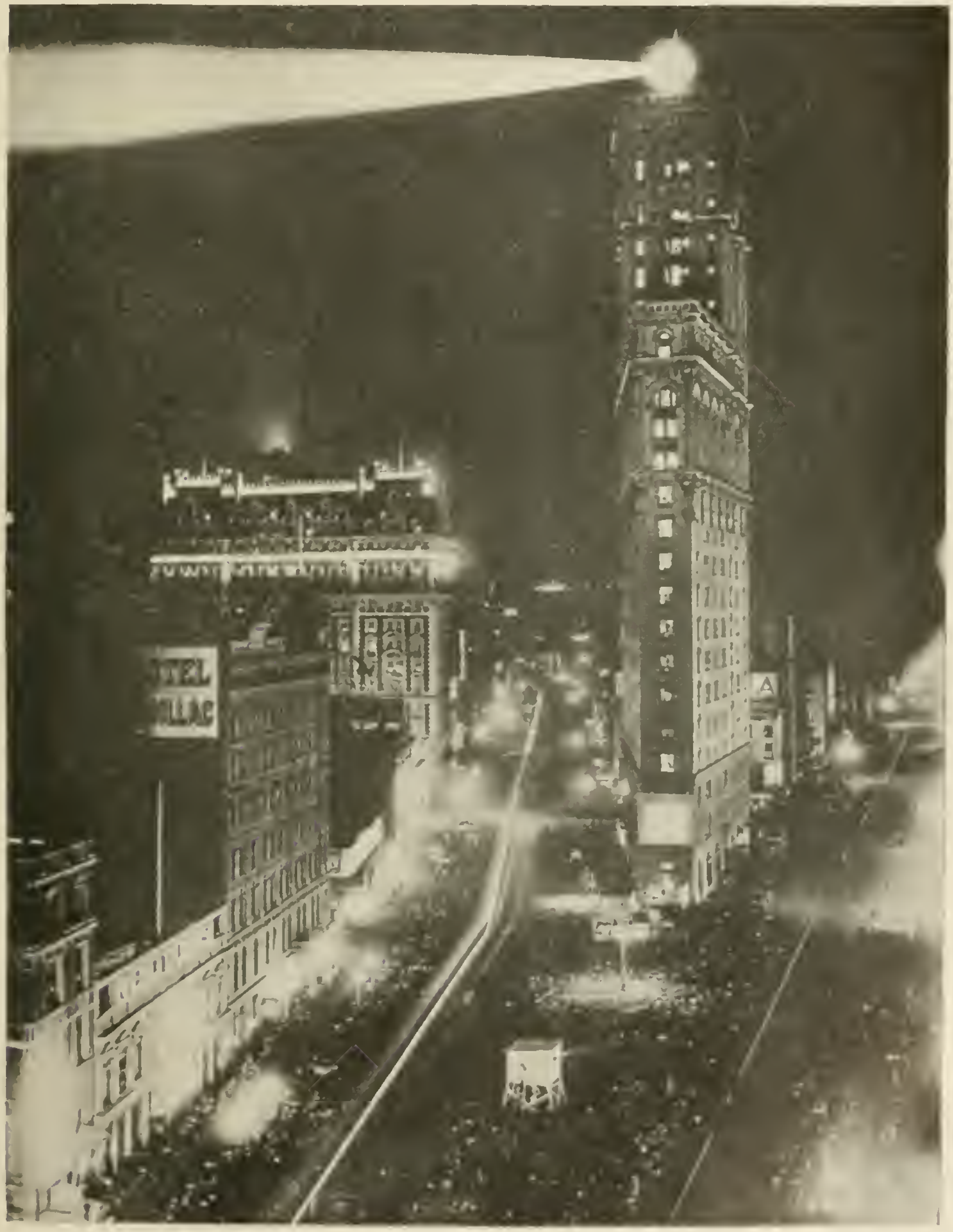


FIG. 14—TIMES SQUARE ON ELECTION NIGHT

The congested masses of people indicate the necessity for having these squares so brilliantly lighted. No direct rays are seen from the lamps, because they were hooded to keep them from shining on the screens on which the election returns were shown.

Hall in Manhattan, north to Yonkers, east to Nassau county, and Central Long Island, as well as its north shore, southeast to

Rockaway, south to Coney Island, and (excepting the ferry) to the southermost point of Staten Island. Cross and inter-connecting roads through country districts are also carefully illuminated. Other projects on this line are now building or planned, such as the Boston Road and Pelham Parkway, and Park to Pelham and the South Shore of Connecticut; another route is via the Eastern Parkway, Brooklyn, to the Merrick Road and the South Shore of Long Island.

This general development is now established on such basic lines that it can develop consistently and without duplication of equipment expense with the use of the present units of illumination, so that until congestion spreads from Manhattan, the lower portion of the Bronx and Brooklyn, to the outlying sections to the extent that a considerable change from overhead line construction to underground subways becomes necessary, the development need only be to units of greater intensity and not a change in system or equipment to any considerable extent.

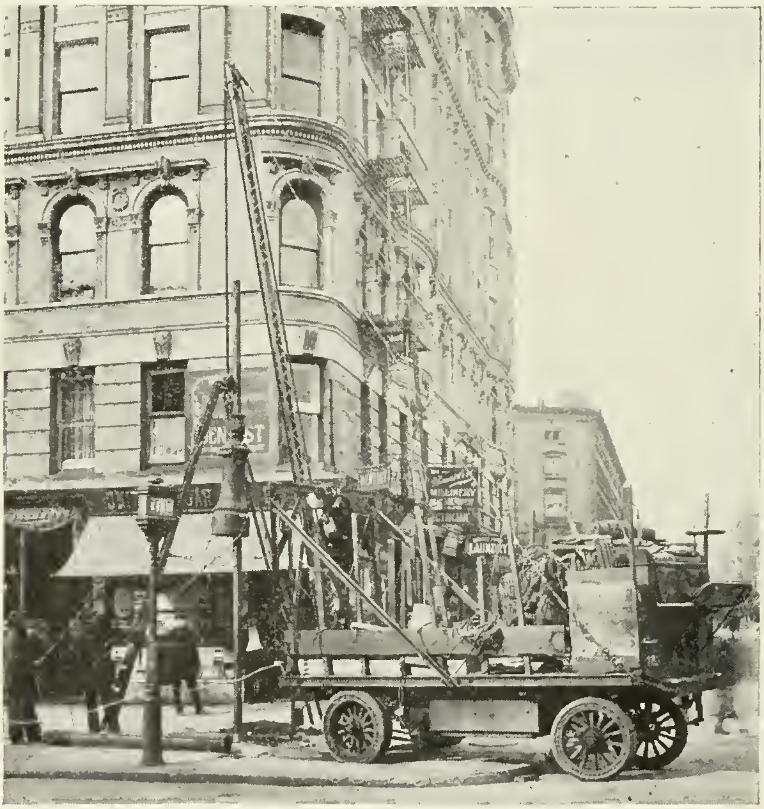


FIG 15—DERRICK WAGON ERECTING A LAMP POST

A certain handicap will exist for some years in obtaining the best distribution of illumination in the suburbs on account of the overhead lighting lines and lighting being kept on one side of the street to avoid duplication of pole lines, but this, in time, will be removed. In the congested area of Manhattan and in the Bronx, where underground distribution exists, the locations of the lamps on the main avenues are secured, and to realize the full perfection of the present plan, only more powerful sources of illumination are needed, and it is to that end the experiments with flaming arc lamps on Broadway and Seventh avenue are being made.

In the development of lighting in this city, we have been careful to avoid freak or too accentuated lighting, on certain streets, as has been the case in some cities. The attempt has always been to keep to uniform, agreeable lighting, avoiding light sources of high intrinsic brilliancy and consequent glare, but where used they are carefully diffused or kept out of the range of vision.

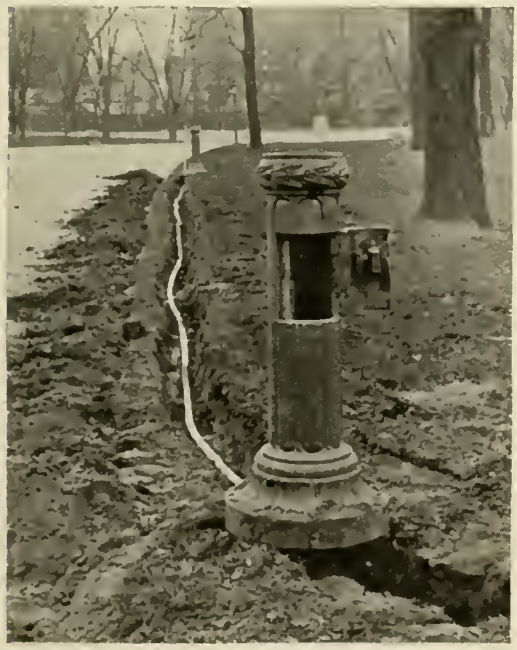


FIG. 16—LEAD COVERED CABLE BETWEEN LAMPS IN THE PARKS IS LAID DIRECTLY IN THE GROUND WITHOUT CONDUIT

It is all a slow, but so far sure progress of evolution, development and education. The results of the original plan of ten years ago are now shown in Manhattan, the Bronx and Richmond, and are beginning to show in the thoroughfares of Brooklyn and Queens. The mixture of lighting units has been generally removed or is in progress of removal. In the last ten years, the illumination of the Greater City, as specifically defined, has increased under this system from seven million candles to fifteen million candles, or an increase of 118 percent.

A peculiar and somewhat odd fact, about all this development is that except in a few isolated instances, no one in this city seems to realize the improvement made in its lighting in later years. Few newspapers have ever mentioned it, and then but casually. No realization that a logical engineering scheme of development is taking place has been noticed, although it has been inherently correct enough to have been supported by the commissioners of four political administrations of the city government. It is only fair to say that the technical journals and societies have discussed it somewhat, and a number of other cities have noticed and studied the lighting and fixtures in use here with a view to their use in their own cities; in some cases our system has been adopted by them.

Even in this, a sort of peculiar pride is taken, for this city, rushing on in its career to the goal of the greatest city of the world, has little time to do much but growl at real or fancied obstructions to its progress. In consequence, to keep up to the extensions of the lighting demanded, the lighting officials of the City Department in charge of lighting have had little time to do anything but work, its efforts being devoted to making up for the lack of development in the past, and hurrying forward to meet the present demands.

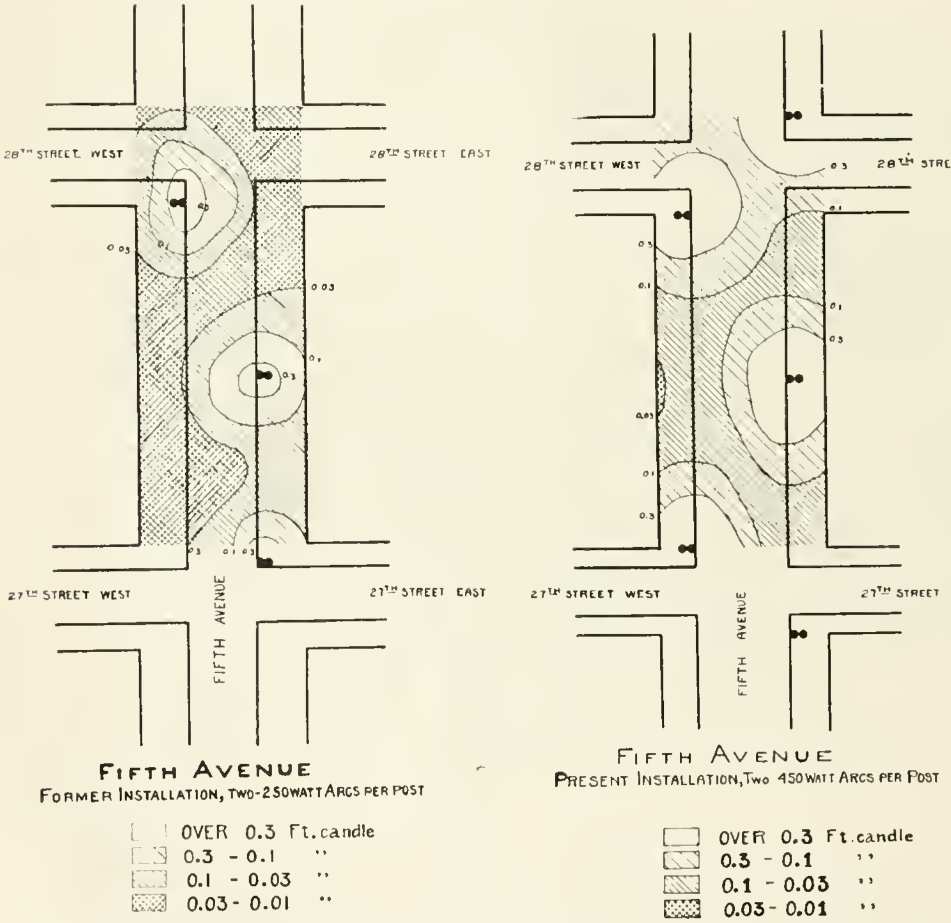


FIG. 17—COMPARISON OF ILLUMINATION FROM TWIN 250 AND 450 WATT ENCLOSED CARBON ARC LAMPS

Compare by areas of equal illumination.

In a negative way, the work has been noticed; for example, since the illumination of the avenues has been doubled and tripled, we have heard complaints that the side streets in Manhattan and the Bronx are dark, and such complaints are always listened to attentively, because they help the engineering scheme by impressing the political and financial powers that be. The side streets are comparatively dark, but in 1904, when the mantle gas lamps replaced the open flame gas lamps, these streets received more than three tims the old illumination, so you can imagine what that illumination was.

This brings up the experiments made last summer to meet this condition. The installation of this new lighting is awaiting the necessary funds. It may be truthfully said that were this city thrown back in a day to the lighting of ten years ago, the contrast would be so extreme that there would probably be great alarm. In the elapsed time the increase has been slow and, in consequence, not noticed perceptibly except from year to year.

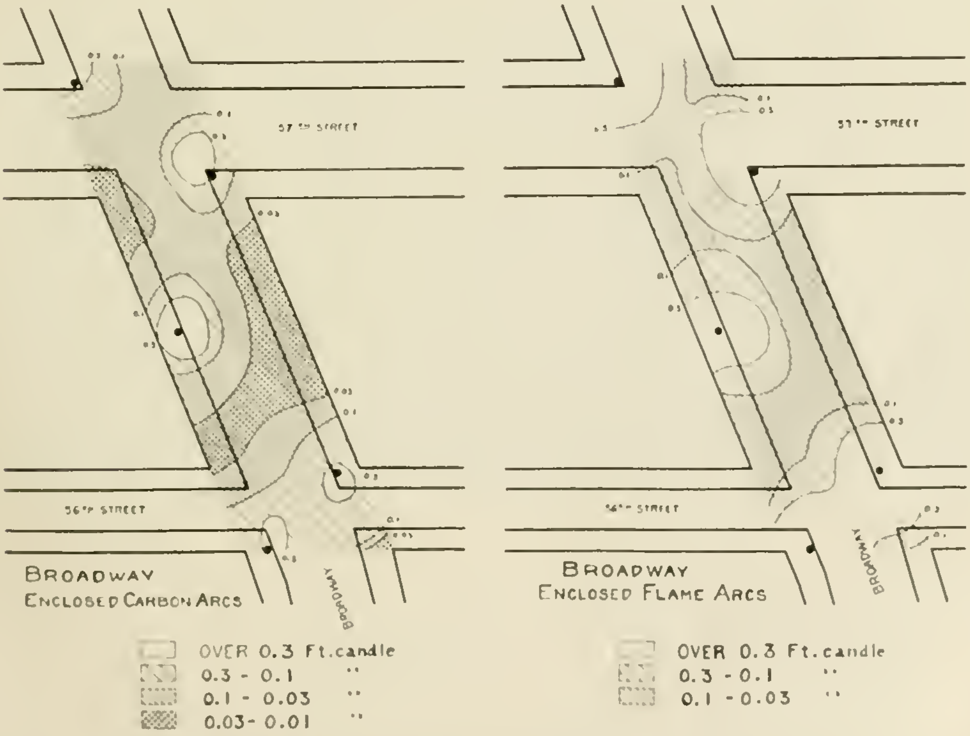


FIG. 18—COMPARISON OF ILLUMINATION BY 450 WATT ENCLOSED CARBON ARCS, AND ENCLOSED FLAME ARCS

The amount of lighting required to secure satisfactory results is determined largely by the use of the streets, but speaking comparitively, it is a matter of education. The example of a street like Fifth avenue or Broadway, attractively and brilliantly lighted, by advertising signs, as well as city lamps, shortly becomes the standard, and requests for increased lighting on other important streets usually refer to it as the type desired.

A poorly lighted city having only poor lighting standards, improves but little, the inhabitants being apparently satisfied. But once begin to improve the street illumination properly and the continuing demand for additional lighting begins. The storekeeper quickly learns the value of a well-lighted street, and the citizens at once realize the comfort of it.

Under the engineering scheme all new lighting is carefully worked out mathematically and geometrically, on lines of proper illumination design. A temporary equipment is then erected, movable if desired, and the final effect obtained by the actual trial and observation on the street. All suitable kinds of reflecting and diffusing devices and glassware are tried until the best result obtainable is reached. This example is then measured and plotted photometrically and checked or corrected, as the case may be. Lighting is no longer installed empirically or by guess work.

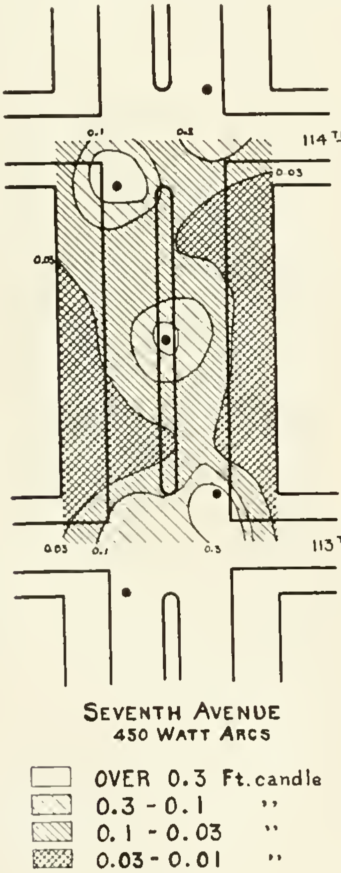


FIG. 19

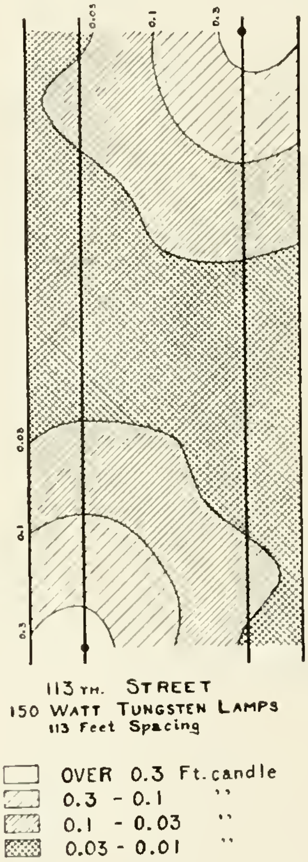


FIG. 20

FIG. 19—ILLUMINATION CURVES FROM 450 WATT ENCLOSED CARBON ARCS ON A STREET HAVING A CENTER PARK-WAY

FIG. 20—ILLUMINATION CURVES FROM 150 WATT TUNGSTEN LAMPS

The newer lamp posts used for the improved lighting are also designed with great care. Even before the Municipal Art Commission took up this matter in a systematic and effective manner, as they did some years ago, the New York Edison Company had anticipated the demand for more attractive fixtures, and have been, and still are, preëminent in this regard. It is well to state here, as one of our working conditions, that with few exceptions the arc lighting posts and fixtures belong to the companies throughout the greater city. The gas lamp posts all belong to the city, as do the tungsten posts in the streets and parks on underground service. The lanterns and lamps themselves belong to the lighting companies. They were first drawn, then life size plaster models made and revised, then the patterns developed and corrected until a satisfactory and harmonious result was attained. They combine artistic effect with engineering construction. These posts are submitted to the Art Commission in every case and their criticisms embodied in the final result. The city's posts also go through this process. In one case the Art Commission had designs drawn and paid for, of both the lanterns and posts for tungsten lamps for Central Park. This design has been used extensively throughout the city since, and has been copied by other cities. The new posts for side street lighting will also be submitted to them, when funds are received, and it is hoped that all the ugly posts will shortly disappear from Manhattan.

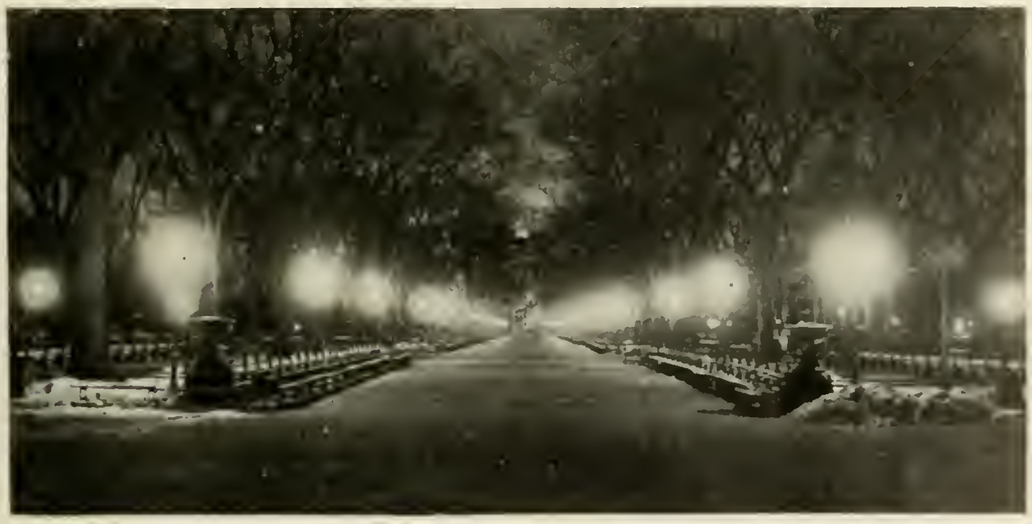


FIG. 21—ILLUMINATION BY TUNGSTEN LAMPS ALONG THE MALL

It is natural that the attempt to make the lighting and fixtures artistic should begin, like the improved lighting system, in the borough of greatest congestion, where it is needed most, and where the lighting is required to be not only useful, but strong, uniform and agreeable. Manhattan is fortunate, in the engineering sense, in being supplied with its lighting service by

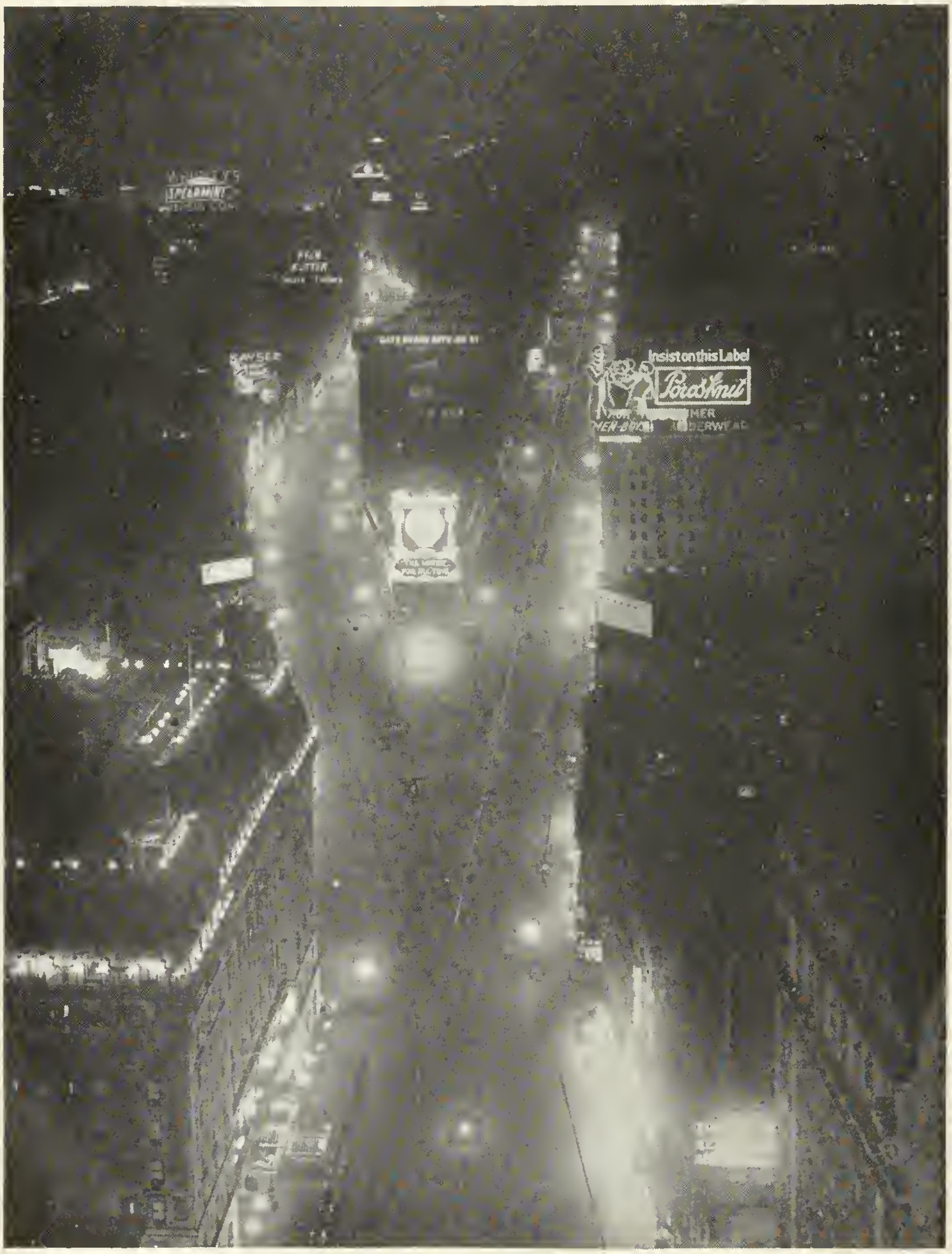


FIG. 22—BROADWAY LOOKING NORTH FROM THE ROOF OF THE TIMES BUILDING

Showing high candle-power flame arc lighting, also electric signs and other private lighting.

a low tension multiple system, which is flexible and very adaptable to artistic effects with safety. This lighting current is distributed by underground lines and, with energy supplied from the greatest electric generating station, gives the best obtainable service.

In addition to the progress made, as here illustrated, it has also been attempted to show, in a limited way, some of the diversified problems of the engineer in the lighting of this great city. He must proportion the lighting to the needs of the various streets or sections, and to their importance, due to greater or less use. He must lay out a system capable of great increase without expensive change of equipment, or the contracting companies will object; he must lay it out on economical and efficient lines and obtain judicially fair prices within limits, or the city administration will object; he must try to eliminate glare, or the illuminating engineers will protest, and he must make it agreeable and as artistic as possible, or the Municipal Art Society and Commission will criticise. Agreeable and successful lighting is a combination of the efforts of all the different interests mentioned. It is not only a matter of artistic posts, but also artistic lighting, if that term may be used. To produce the best results, one must have the support of the city and the contracting company. The posts and the lighting must both be artistic and agreeable. The position, height and design of the supporting post have much to do with the effect of the distribution of the lighting, as well as its cost. In the combina-

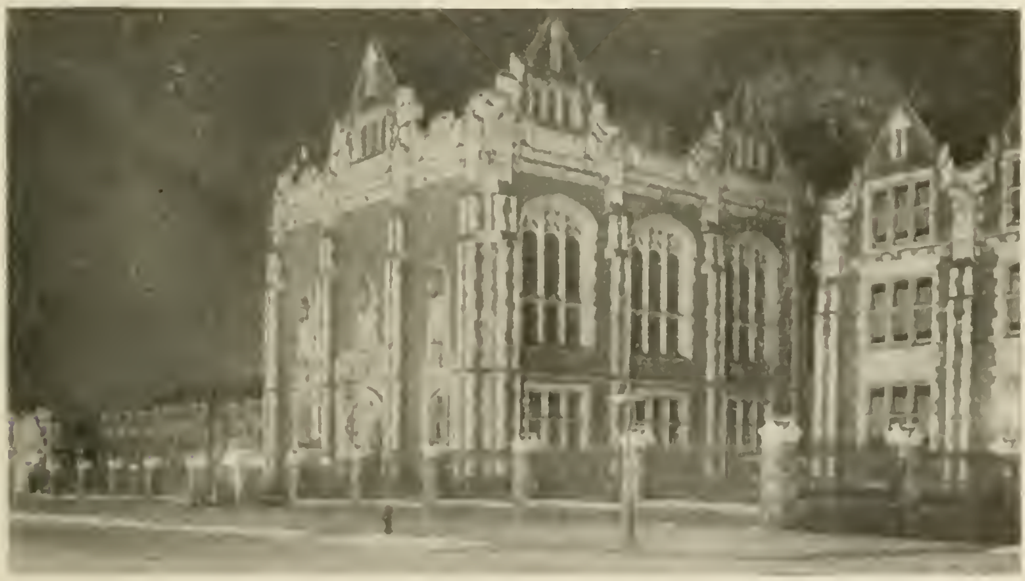


FIG. 23—CITY COLLEGE BUILDINGS AT NIGHT

This building is lighted from lamps across the street. In other words, when looking at the building no lights glare in the eyes and the complete architectural effect is brought out almost as well at night as in the day time. The City Public Library is also lighted by. this method. The illumination on the buildings is about 0.1 candle-foot.

tion of these elements the municipal administration, the company, the artist and the engineer can well work together. The administration should provide the necessary funds for steady progress in lighting, both in extension of service and improvement in illuminating units, etc. Within limitations the artist must not demand too extremely, artistic design in lighting. It is too costly, except in certain instances. In the general lighting of a great city, the useful side must have as great weight as the artistic. The engineer also should not cling too closely to the most efficient and economical devices, which obtain only the greatest illumination at the lowest cost, for the lighting must be made agreeable to the eye.

In street lighting, unless surrounding buildings are to be specially illuminated, the useful rays are those that can be directed towards the ground. To make this agreeable, the point source of an arc lamp, for instance, must be made into a ball of softened light by diffusing globes or shades, and this, so far as is possible, thrown toward the ground by either interior or exterior reflectors. This loses efficiency to a certain amount by the absorption of the light, and demands either closer spacing or more powerful sources of illumination at greater heights from the ground. It is, consequently, more expensive. So far, it has been used mainly in Manhattan, and there principally on its main avenues. In other locations, we approach nearer to the naked source of the light. This, in turn, means glare and is not as agreeable, although very useful and less expensive. Considerable success in suburban sections of the city has also been attained by abandoning the intense arc unit and using three to four 60-70 candle power tungsten lamps, and so obtaining better distribution, with less glare, and at about the same cost. It is to the work of aiding in the extension of diffused lighting in sufficient amount that the efforts of all should be devoted. The administration, the company, the citizen, the artist and the engineer should all work to this end. The progress of this lighting depends on the aid the other factors in this work give the engineers in charge.

There is nothing new in this plan of lighting. The ancient torch bearer always held his torch as high as possible to avoid glare and to throw the rays over as great an area as possible. The engineer uses his new facilities for lighting in the same way, puts the lamps as high as possible, and throws the light over the greatest area he can. He only adds to the torch bearer's efforts, the diffusing globes and the downward reflectors.

In the Borough of Manhattan, the locations of the posts for street lighting have been obtained and need only more powerful illuminating units in order to bring out the full effect of the proposed system. During the past year more powerful and efficient sources of illumination have arrived, both in small and large units. The increased efficiency of the tungsten lamp, which is the smaller unit, gives us more illumination per unit for the same energy than formerly, so that in the suburban districts, we can increase the illumination by changing lamp for lamp without any more expense for energy consumption. With the 150-watt unit for side streets in Manhattan, excellent results will be obtained on these streets.

The larger unit, the flaming arc lamp of the long burning type, is now nearly perfected, its illuminating power per watt makes it very desirable, and it is now being used and will be used to illuminate streets in the center of the city in those areas which are congested at night.

The further development of both the tungsten and flaming arc lamp is now an assured fact, and it is with these two main units that we hope to work out the further illumination of the city. In addition to these, luminous lamps can be used in districts where series arc lighting is in vogue. The flame arc lamp and the magnetite lamp are both types which could be used in important sections or streets. By far the greater territory in the city will be covered for a long time to come, however, with our old standby, the standard enclosed carbon arc lamp and the mantle gas lamp, with either upright or inverted mantles. It is believed that with these illuminating units and the use of the same care in the future, the lightning of the city can go forward as rapidly as desired within the physical and financial limitations, and in due time will become not only an attractively lighted city, but the best lighted city in the world.

ECONOMIC LIGHTING OF STREET CARS

S. G. HIBBEN and E. M. SMITH

DISTINCTLY economic methods of lighting street cars have, until the present time, been developed but very little. The use of high efficiency tungsten lamps and properly designed reflectors has been extended to practically every other large field where continued artificial illumination is required, even to the lighting of steam railway coaches, but the inefficient method involving bare carbon filament lamps is yet in vogue with the majority of city and surburban electric railway companies. Several companies have replaced their carbon lamps (usually of the 64 watt, 16 c-p size) with 23-25 watt tungsten lamps in the same sockets, which is admittedly a step towards economy, but which fails to secure the best utilization of the generated light flux because of the lack of reflectors, and violates the first principles of optical hygiene. To reduce the total cost of wiring and fixtures, to utilize a higher percentage of the light flux and to protect the eyes of passengers, are problems which are solved by the use of a smaller number of shielded lamps.

By the use of a modern system similar to the one herein outlined, a considerable saving of current will result, accompanied by a large increase in the amount and pleasing qualities of the resultant light. Current at the car is expensive, even though it is generated cheaply. Perhaps the reason for the slow growth of methods of strict economy in street car lighting is that the lighting expense is not so apparent as it is in steam railway or storage battery service. But any considerable saving of current may mean more power for traction; more cars in service with the same power plant equipment; less copper cost for distribution; extra power for heating, for moving signs, or for brakes; or decreased all-around costs of operation per car-mile.

Any improvements in the illumination are very consciously apparent and pleasing to the passengers, since in these cars there is a great amount of reading of fine print under adverse conditions of jarring and of voltage fluctuations. During rush hours, and especially when cars are accelerating or climbing grades, the old lighting systems are more than unsatisfactory.

THE LIGHTING EQUIPMENT

The average car lighting equipment at present consists of 17 to 22 of the so-called 16 candle-power, or 64 watt carbon filament lamps arranged on the center deck of the car, and from 8 to 13 similar lamps distributed on the platforms and in the headlight and signs. Such lamps are rated at 110 volts, burning in groups of five in series on the nominal 550 volt power circuit, and have no shades or reflectors.

The most modern car lighting equipment consists of five 85 to 90 candle-power, 94-100 watt Mazda lamps, arranged four in the car body and one on the rear platform, supplemented (in all cars but trailers) by a circuit of five nominal 25 watt Mazda lamps, for the front vestibule, headlight, sign, and over the car steps. Fig. 1 illustrates an interior view of a car with this arrangement.

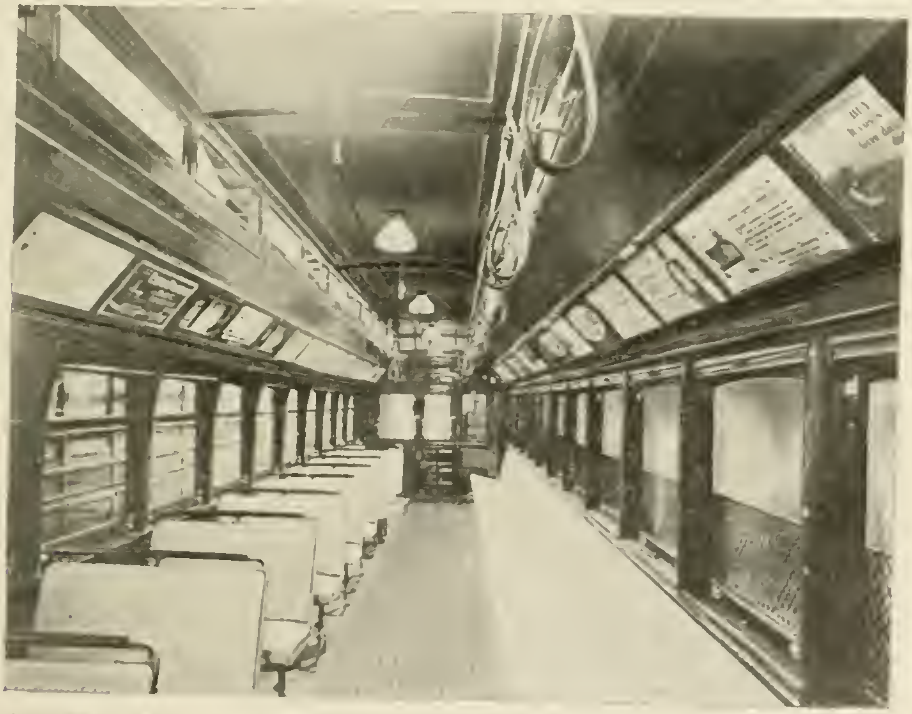


FIG. 1—STREET CAR INTERIOR EQUIPPED WITH FOUR 90 CANDLE-POWER 94-100 WATT MAZDA LAMPS

The five large lamps are equipped with a deep-bowl type of Alba glass reflector to redirect the light to the seat level. An auxiliary lamp is wired in each circuit, and ordinarily shunted through a manual selector switch. This auxiliary lamp is usually located on the rear platform.

A plan of the arrangement of the main lighting units is shown in Fig. 2. Fig. 3 shows the wiring diagram. Unit Number 1 will be shunted in the present position of the switch contacts, since the switch arm bridges two contact points. By moving this arm around, successive lamps will be cut out and any burnt-out lamp can in this way be quickly detected, and cut out of circuit or bridged around, so that continuous lighting service is secured. When the car reaches the end of the line, or at any convenient stop, the auxiliary rear platform lamp may be substituted for the burnt-out lamp. The brass fixtures holding the reflectors are of a type that clamp completely around the necks of the shades, and will not work loose by jarring. A short porcelain receptacle for the lamp base may be set into holes in the deck, or the receptacle may extend some three inches below the deck and be attached by four wood-screws.

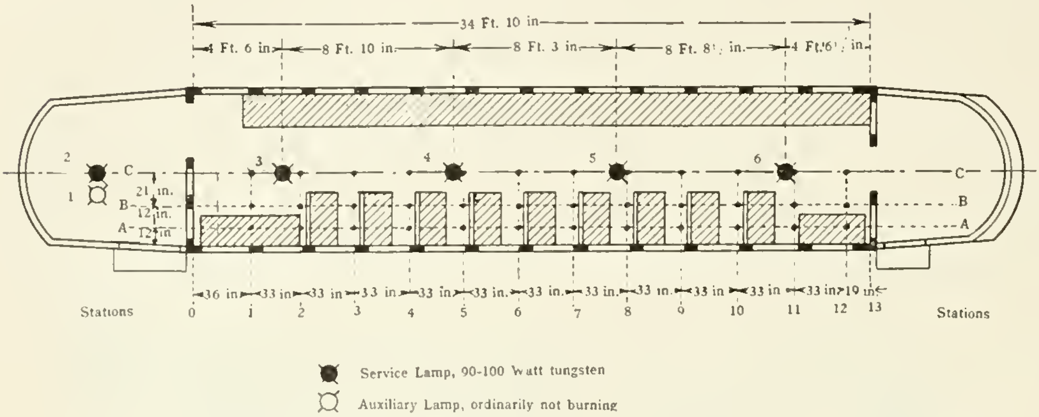


FIG. 2—LIGHTING ARRANGEMENT PLAN FOR MAIN 100 WATT UNITS SHOWN IN FIG. 1

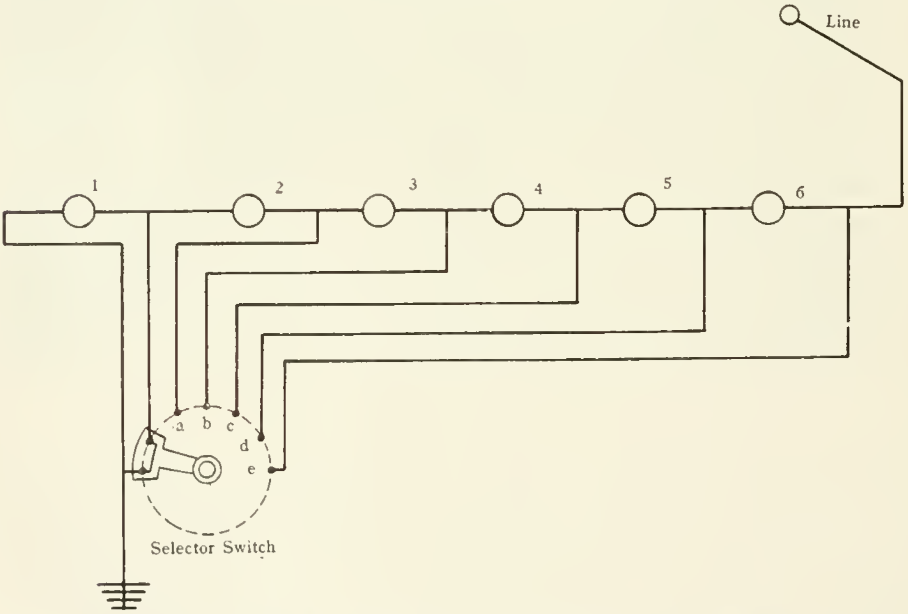


FIG. 3—WIRING DIAGRAM OF 100 WATT TUNGSTEN SYSTEM SHOWING METHOD OF SHORT-CIRCUITING A BURNT OUT LAMP

ILLUMINATION COMPARISONS

The new lighting system with the few large shaded units is far ahead of any of the previous methods in efficiency of illumination. Typical comparison tests are summarized graphically in Fig. 4. These curves are the results of photometric measurements taken at the stations shown on the plan, (Fig. 2) at the intersections of longitudinal lines *A* and *B* and the twelve transverse lines *1* to *12*. Readings of foot-candles were made in the car body only, at the passenger's reading height of 37 inches, upon first an average unshaded lamp equipment, and second, the new shaded equipment. The results are recorded in Table I. A comparison of the full-line curves of Fig. 4, representing illumination with the new system, with the dotted-line curves of the old system, meanwhile keeping in mind the 65 percent reduction in current, certainly makes apparent the supremacy of the newer

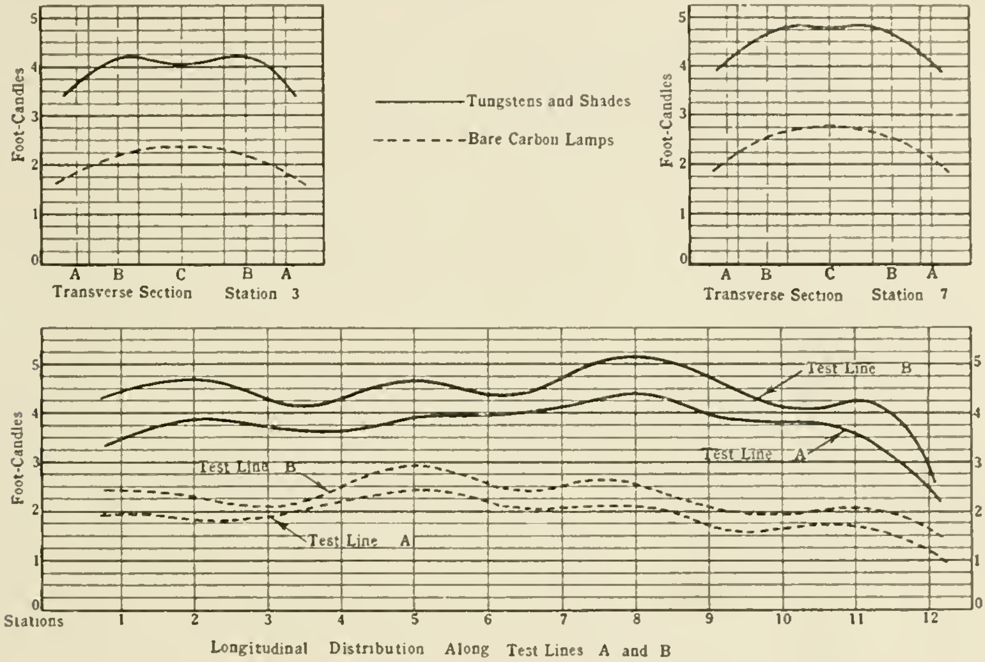


FIG. 4—LIGHT DISTRIBUTION CURVES ALONG TRANSVERSE AND LONGITUDINAL CAR SECTIONS

Showing comparison between old bare carbon lamp methods and more modern shaded tungsten system shown in Figs 1 and 2.

TABLE I—LIGHTING PERFORMANCE

	Carbon Lamps	Tungsten Lamps
Number of Lamps (Car Body)	17	[illegible]
Total Nominal Wattage	1088	376
Watts per Sq. Ft. of Floor	3.83	[illegible]
Average Illumination—Foot-candles	2.30	4.19
Effective Lumens per Watt	0.60	3.10
Lighting Results—Percent	11.1	100

method. And yet the curves tell only a part of the story, for it is impossible to present in print the neat, decorative features of equipment or the diffused illumination characteristics.

It has been stated that the use of unshaded small Mazda lamps was but the beginning of progress towards high efficiency. With the former equipment of 17 sixteen candle-power carbon lamps the total generated lumens was about 2 890, while the four eighty-five candle-power Mazda lamps furnish 3 120 lumens. This shows an increase in generated light (when using Mazda lamps) of only eight percent, but due to the reflection of the light to a useful plane by the Alba shades, the effective or usable light may be increased some 80 percent (2.3 to 4.2 foot-candles). Not only is the illumination with the new system of a higher value, but it is also more uniform under the unavoidable conditions of voltage fluctuations. During the periods when there is a heavy demand for current, the resultant low pressure has caused severe reductions in candle-power when using carbon lamps, and the original lighting equipment has necessarily been made large enough in wattage to provide light during these most adverse periods. This is not necessary with the Mazda lamps since, as may be seen from Fig. 5, the decrease in voltage does not cause nearly so large a decrease in candle-power with these lamps as with the carbon lamps. For instance, if 500 volts be the average pressure at the lamps, a reduction to 460 volts will result in a candle-power decrease to 56 percent of the initial value when using carbon lamps, but with

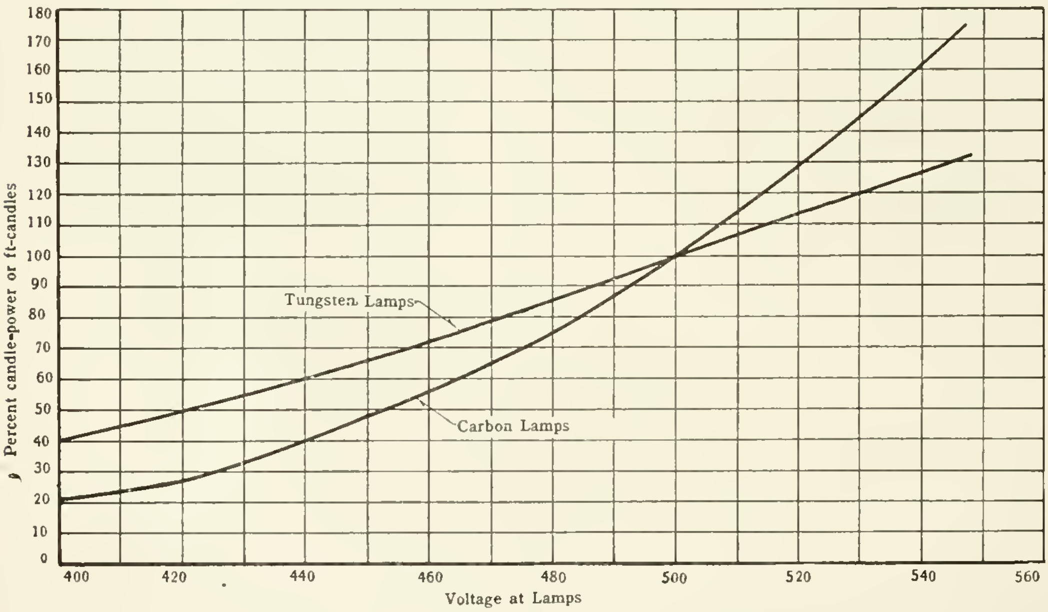


FIG. 5—CURVES SHOWING COMPARISON OF EFFECTS OF VOLTAGE VARIATION ON CARBON AND TUNGSTEN LAMPS FOR STREET CAR SERVICE

Mazda lamps this will be a decrease to but 72 percent of the initial. The life of tungsten filament lamps has been proven to be very good in street railway service. In one city, an installation of 23 watt tungstens averaged 1 300 hours. The rated life (at bottom voltage) of the 100-watt lamps is approximately 1 700 hours, and even one half of this life would still mean a large margin of saving in operating costs.

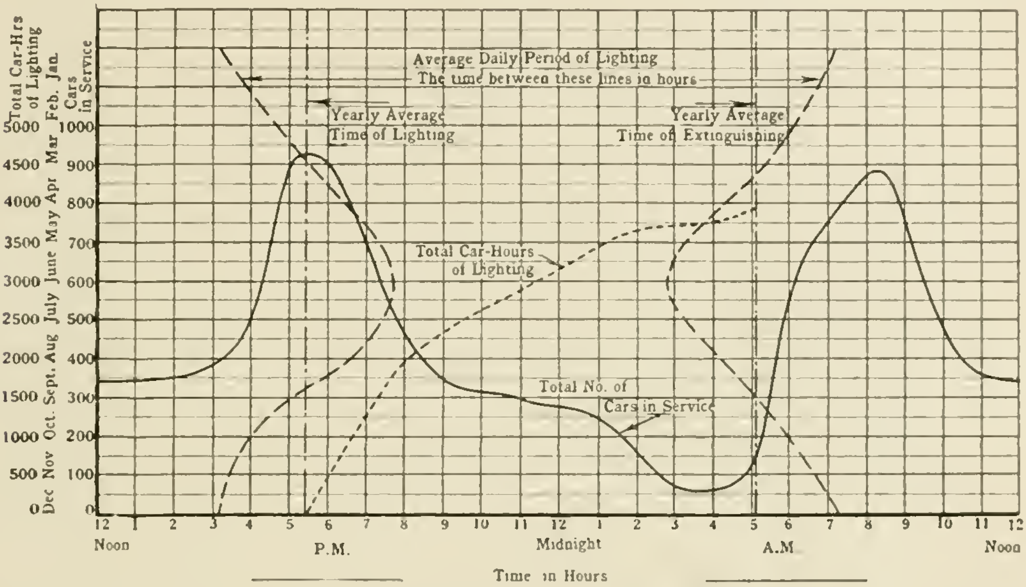


FIG. 6—RAILWAY OPERATING CHARACTERISTICS FOR A TYPICAL UNITED STATES CITY OF 600 000 PEOPLE

COST COMPARISON

It is interesting to note some representative cost figures that are based on the characteristics of a street railway system of a city of medium size. Such characteristics are shown in Fig. 6, giving the daily number of cars in service, the average daily period between the average hours of turning on the lights and of extinguishing them. It may be seen that there are nearly 4 000 car-hours of artificial lighting each day, or about 1 500 000 per year. Based on these figures, a cost summary will be about as shown in Table II,

TABLE II—LIGHTING COSTS

	Carbon Lamps	Tungsten Lamps	
Car-hours of Lighting per Year.....	1 500 000	1 500 000	
Average Number of Lamps per Car..	22.4	5—100 Watt	4.5—23 Watt
Lamp-hours of Illumination per Year.	33 600 000	7 500 000	6 750 000
Average Life of Lamp—Hours......	1 800	800 (est.)	1 300
Yearly Number of Lamp Renewals...	18 700	9 380	5 180
Net Cost of Lamps (on contract)...	$ 2 730	$6 280	$1 130
Net Cost of Lamps (Total).......		$ 7 710	
Yearly Cost of Power............	$55 500	$14 150	
Expense of Shade Equipment (est.)..		$ 3 000	
Final Total Yearly Cost...........	$58 230	$24 860	

in that a conservative life of 800 hours has been assigned to the large Mazda lamps. The yearly expense of a shade equipment has been based upon interest on investment, breakage and depreciation, and cleaning costs. The combined wiring and fixture costs when equipping new cars with either the new or the old systems, are practically equal.

CONCLUSIONS

Briefly, it is apparent from an analytical study that the Mazda lamp Alba-shade equipment greatly reduces lighting costs, which reduction in a railway system operating 1 000 cars will be at least $13 000 a year and probably $15 000 as the life of the lamps exceeds 800 hours. The resultant useful illumination can be increased 80 percent, while at the same time securing a cost reduction of about 40 percent. With Mazda lamps, voltage variations will not cause such large candle-power variations as occur with carbon lamps. Continuous lighting service may be secured by means of a selector switch or an equivalent device. Lamps placed deep in intensive reflecting shades are optically harmless, and the complete unit becomes pleasing. These factors, and others of minor importance that might be mentioned, will serve to indicate the possibilities, and a careful consideration of this subject will show why most street railway companies are realizing that they can no longer afford to continue the old inefficient lighting methods.

LONG BURNING FLAME CARBON ARC LAMPS

G. W. ROOSA

THE trend of improvement in arc lamps has been constantly toward a lamp that will give maximum useful light, that will operate for a period of reasonable length between trims, that will show a minimum depreciation in candle-power up to the end of the trim, that will be positive and simple in operation, and which will operate with the lowest maintenance costs for a given amount of light. To a large extent these problems have been met by the flame carbon arc lamp using high efficiency electrodes composed of homogeneous mixtures of carbon and certain mineral salts. By introducing a proper proportion of cerium salts, a carbon giving white light is produced; one containing calcium salts gives a yellow light. The high temperature of the carbon arc is such as to volatilize these salts and their vapors give off light of great intensity.

TABLE I—APPLICATION OF FLAME CARBON ARC LAMPS

Lamp	Application	Light	Life
Alternating Current—Series	Boulevard Lighting	White or yellow	100 to 125 hrs.
	Street Lighting	White or yellow	" " " "
	Yard Lighting	Yellow	" " " "
Alternating Current—Multiple	Industrial Lighting—Advertising	Yellow or white	" " " "
Direct Current—Multiple	Industrial Lighting—Advertising	Yellow or white	" " " "
Direct Current—Multiple-Series	Industrial Lighting	Yellow or white	" " " "

During the operation of flame carbon arc lamps of the earliest type, the vaporous by-products condensed upon the globe in the form of a white opaque powder, the accumulation of which by the end of the trim, usually ten to fifteen hours, caused an undesirable depreciation in illumination. Long burning carbons, then, mean an excessive depreciation in candle-power, and the use of short-life carbons means frequent renewals with attendant high costs. By carefully enclosing the arc with a small globe, condensation on the globe is reduced to a point sufficient to allow the use of carbons giving a desirable life. If this enclosure is properly made the life can be increased to that of the well-known enclosed carbon arc lamps. To accomplish this, and at the same time provide a means of disposing of the vapors a condensing chamber is provided above the arc, within which pieces of magnesia or other substance are placed to absorb the gases.

Having incorporated these essentials, the flame carbon arc lamp illustrated in Fig. 1 resulted. For indoor use a single globe may be used, but the deposit on the glass is less with two globes. The latter arrangement is common practice for street lighting. Such a lamp may be designed for alternating or direct-current circuits, and may be operated on multiple or series circuits. The varied application of the lamp may be seen from Table I, which includes the commercial types available.

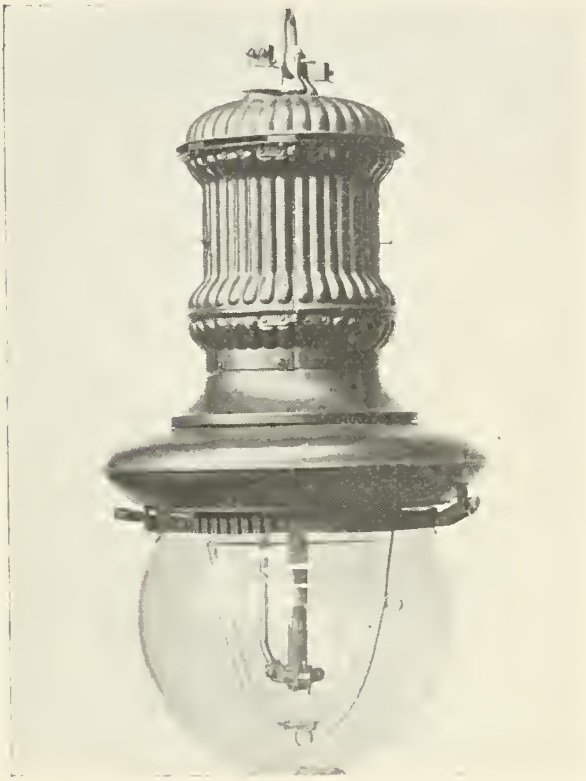


FIG. 1—ONE HUNDRED HOUR SERIES ALTERNATING-CURRENT FLAME CARBON ARC LAMP

ALTERNATING-CURRENT LAMPS

As the most efficient current rating practicable for flame carbon arc lamps is ten amperes, the auto-transformer shown in Fig. 2 may be used for alternating-current service, where a few lamps are to be placed upon the existing street lighting circuit of 6.6 or 7.5 amperes, thus raising the current at the arc to 10 amperes. In larger new installations, old regulators can be readily and cheaply rewound for ten amperes, thus saving the cost of auto-transformers or new regulators. In either event the total initial and maintenance costs for a given amount of light would be less than when a 6.6 or 7.5 ampere arc is used. With hardly a single exception, white light carbons are being used for street lighting. The light maintains a steady penetrating value 20 percent below that of the yellow light carbons.

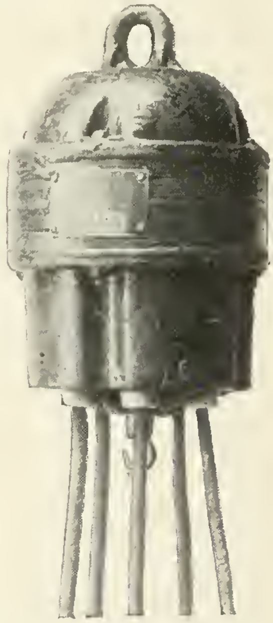


FIG. 2—SERIES AUTO-TRANSFORMER FOR BURNING TEN AMPERE LAMPS ON A 6.6 OR 7.5 AMPERE SERIES CIRCUIT

When operated on 25 cycles this new lamp is a decided improvement upon the enclosed carbon lamp designed for the same frequency from the standpoint of illumination. Although there is perceptible flicker, if the lamp is mounted high and the field illuminated does not contain rapidly moving objects, it cannot be detected by the average person. The alternating-current multiple lamp for 220-volt, 25-cycle circuits, or 440-volt, 60-cycle and 25-cycle circuits may be operated with external auto-transformers. Those for the more common circuits are self-contained; that is, the lamp and auto-transformer are complete in one casing. The function of the auto-transformer is to reduce the line potential to the proper arc voltage and supply ten amperes to the arc. The ballast necessary for multiple arcs is obtained by designing the auto-transformer to give the desired reactive effect.

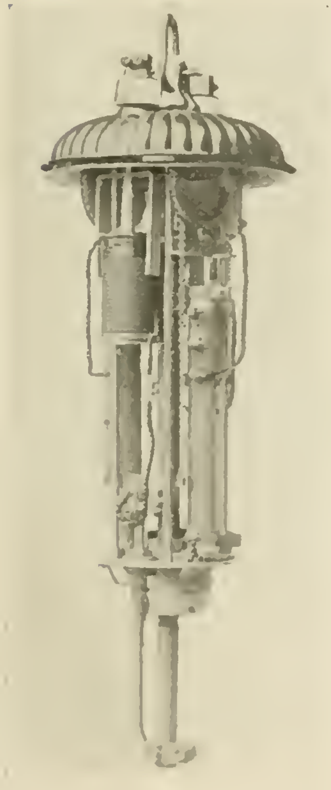


FIG. 3—DIRECT - CURRENT MULTIPLE FLAME CARBON ARC LAMP

DIRECT-CURRENT LAMPS

The direct-current multiple lamp is designed to operate at 6.5 amperes with 70 volts at the arc. To consume ten amperes would mean a lamp of over one kilowatt capacity and excessive waste of energy in necessary ballasting resistance. This lamp is shown in Fig. 3.

The direct-current multiple-series lamp, for reasons as obvious as those pertaining to the direct-current multiple lamp, is operated at 6.5 amperes; two of these lamps being commonly used in series on 220 volts. Many steel plants and industrial companies will use this type for reasons of high intensity and low cost of operation.

PERFORMANCE AND CHARACTERISTICS

The electric performance of the various types of flame carbon arc lamps is given in Table II.

Distribution and illumination curves of the flame carbon arc lamp are shown in Figs. 4 and 5. It will readily be seen that the use of diffusing glassware reduces the maximum points and increases the minimum points of the distribution curve, and that, in general, it lowers the illumination somewhat. The actual candle-power obtained from flame carbons can be increased materially so as to give a maximum value as high as 2 500 candle-power with 450 watts. Good practice requires a carbon giving a moderate candle-power value, as the other conditions, such as unsteadiness and slagging, increase when the necessary materials are introduced to give the very high values.

MECHANICAL OPERATION

TABLE II—ELECTRICAL CHARACTERISTICS OF FLAME CARBON ARC LAMPS

Type of Lamp	Terminal Watts	Terminal Volts	Arc Amperes	Arc Volts	Electrical Eff.—Percent.	Power Factor
A-C Series.	450	55	10	47	88.0	82
A-C Multiple.	450	100 to 120	10	45	81.0	61
D-C Multiple.	715	100 to 120	6.5	70	63.6	..
D.C Multiple—Series. . .	715	100 to 120	6.5	70	63.6	..

TABLE III—ILLUMINATION CHARACTERISTICS OF LAMPS EQUIPPED WITH CLEAR GLASSWARE

Type of Lamp	Angle of Max. Cp Below Horizontal	Max. Cp	M. L. H. Cp per Watt	Total Downward Lumens
Direct-Current Series, 6.6 ampere enclosed carbon lamp 480 watts.	40 to 50 degrees	620	.94	2825
Direct-Current 4 ampere metallic flame arc lamp, 272 watts	10 to 15 degrees	650	1.82	3250
350, Cp Tungsten street series lamp with 22-inch reflector, 350 watts.	10 to 40 degrees	420	0.952	2375
Alternating - Current Series Flame Carbon lamp, 450 watts, white light carbons	5 to 30 degrees	1700	3.02	8725
Alternating - Current Series Flame Carbon lamp, 450 watts, yellow light carbons	5 to 30 degrees	2000	3.57	9960

To understand the mechanism fully one should be acquainted with the operation required of it; and to grasp the necessity for other minor but essential parts of the lamp, it is best to understand in what manner the flame carbon arc is different from other arcs. It has been universal practice to locate the mechanism above the arc, thus securing as much useful light in the lower hemisphere as possible. Two relative positions of the carbons have been in vogue in arc lamp practice, one known as "Inclined Carbons" and the other as "Vertical Carbons". In the former arrangement two converging carbons are so placed that the arc is between their lower tips. The maximum light from such an arrangement is thrown vertically downward and much less outward. In the latter arrangement, which is more common, two carbons are placed in a vertical position, one above the other. This is a more logical arrangement for flame carbon arc lamps, where the larger part of the light is emitted from the arc path. The distribution curve in Fig. 4 shows considerable light at such angles as to make the lamp useful for street lighting as well as for large interiors. It is required, then, that the mechanism be such as to allow the vertical arrangement.

Early experiments on the electric arc between carbons impregnated with mineral salts indicated that a higher luminous efficiency is obtained when the arc is burning in a pocket of heated gases. It was also found that by placing an inverted cup-shaped piece above the arc, through which the upper carbon passed, climbing of the arc upward on the upper carbon was prevented. Commercially these points are taken care of by the economizer, Fig. 7. It provides a suitable pocket for the heated gases, prevents the free entrance of air from the rest of the lamp, provides, after a few hours of condensation of the white powder, a fair reflection and diffusion, and steadies the arc, thus improving the quality of the illumination.

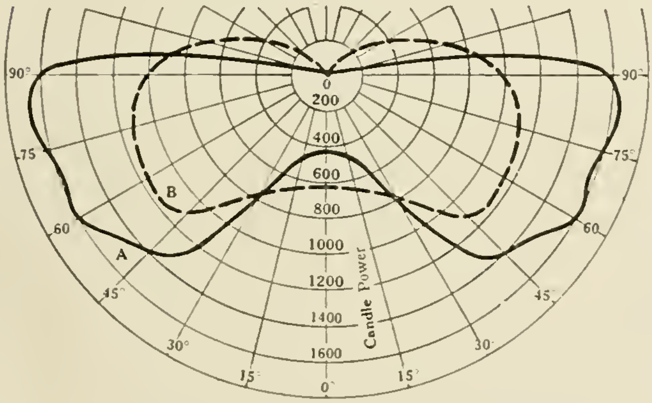


FIG. 4—DISTRIBUTION CURVES

Candle-power at various angles in a vertical plane with *A* clear inner and outer globes, *B* clear inner and Marbo outer globe.

If this lamp were made with a mechanism similar to that of the enclosed carbon lamp, which regulates only the upper carbon, a few hours of burning would burn off the lower carbon to a position where the arc would be operating too far below the economizer to obtain the above advantages. Thus it becomes necessary to provide a focusing mechanism, which feeds both carbons at such a rate that the arc is kept approximately a constant distance below the economizer. This is accomplished by connecting the upper and lower carbons mechanically by means of chains run over the double pulleys *EF*, so that a movement of one means a movement of the other. The upper carbon is usually hotter as it is in a pocket of heated gases held by the economizer. In the case of the direct-current lamp, where the upper is the positive carbon, greater heat is produced here than at the lower. As the result of research and experience it has been determined that the upper carbon is consumed about 1.65 times as fast as the lower and should therefore be fed faster in order to maintain the desired constant position of the arc. Referring to Fig. 6, it may be seen that the chain *U* from the upper carbon is fastened and passes up over the larger part of the double pulley *F* and that the chain *L* from the lower carbon holder is affixed in a similar manner to the smaller part *E*. A rotation of the pulley will cause the upper carbon to move about 1.65 times as fast as the lower carbon, thus compensating for the difference in carbon consumption.

The mechanism is so arranged that on starting the arc the carbons are together and, in case of failure of the arc, the carbons will come in contact. The upper carbon holder *G* is heavy, causing the carbons to fall together with sufficient force to eradicate the slag troubles found in the early development of flame carbons.

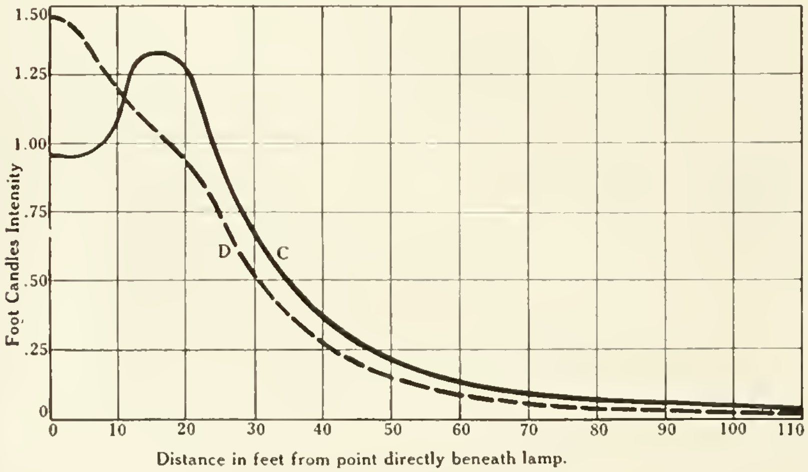


FIG. 5—ILLUMINATION CURVES
C—Derived from Curve *A*, Fig. 4.
D—Derived from Curve *B*, Fig. 4.

The mechanism provides for starting, regulating, feeding and stopping when the trim is completed. To illustrate these operations consider the alternating-current series lamp. Here the arc is started by the usual differential arrangement of shunt and series coils. The series coil draws the rocker arm down, thus lifting the upper carbn slightly, and lowering the lower carbon so that the voltage across the arc, which is the voltage across the shunt coil, energizes the shunt coil enabling it to equalize the pull of the series coil on the rocker arm *N*. It is unnecessary to go into a detailed explanation of the method of gripping the upper carbon, as the well-known sneak feed clutch is employed. It holds a ring of tool steel whose interior diameter is slightly greater than that of the carbon. The manufacture of flame carbons has been perfected so that carbons vary but little in diameter. Those intended for use in the flame carbon arc lamps described, are guaranteed to be within such a limit of variation that will assure little effect upon arc length and the lamp operation.

Regulation of the arc is obtained through the application of the usual rocker arm principle, changes in voltage and current actuating the rocker arm about the fulcrum *A* in Fig. 6. It is of decided importance that minimum friction during regulation should exist. By referring to the diagram of the series lamp it will be seen that the regulation means a constant motion of the carbons, brought about through a "see-saw" action of the rocker arm. As the upper carbon holder *G* is guided by the two clutch rods (one is shown in the diagram as *Y*) there is no relative motion between them. Thus friction is eliminated at this point. From the location of the double pulley *E-F*, of which there are two (one is shown in the diagram), it will be seen that as the point on the edge of the pulley *E*, at which the chain *L* leaves the pulley, moves upward and downward with the rocker arm, the regulating motion requires no rotation of the pulley on its axis, thus eliminating friction at this point also. If their centers were at the fulcrum they would have to be much larger in diameter to give proper separation of the carbons.

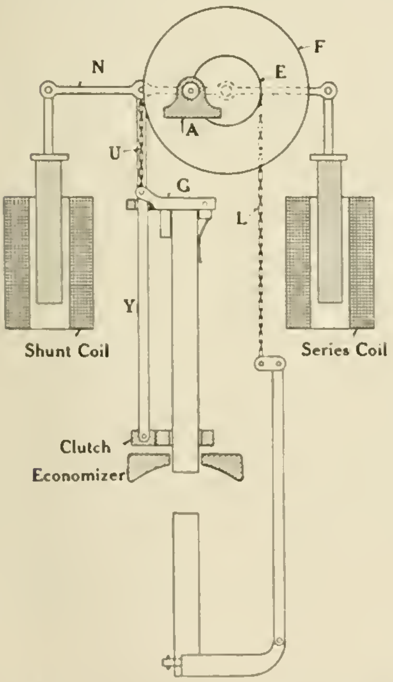


FIG. 6—ALTERNATING-CURRENT FLAME CARBON ARC LAMP MECHANISM

Feeding of the carbons occurs when the pull of the shunt coil has increased enough, through the gradual increase in arc length and thus arc voltage, due to the carbon consumption, to allow the clutch rod *Y* and clutch to be lowered to the releasing point. During the feeding operation the pulleys, chains, and the carbon holders move relative to the rocker arm. The life of one trim is ended by a mechanical stop which prevents the arc from burning down to the lower carbon holder. The stub of the lower carbon is thrown away. The stub of the upper carbon is inserted in the lower position, after a new 14-inch carbon has been placed in the upper holder.

A discussion of this new lamp would not be complete without reference to enclosure and weathering conditions. The construction and design make all parts accessible for repairs through two doors in the casing. They are over-lapped to prevent the entrance of rain, snow and insects. As pointed out above, the arc chamber consists of two parts, namely, the inner globe and the condenser. The arc lamp trimmer should appreciate that success in attaining even longer life than 100 hours lies within his power. Nicked or cracked globes should not be used. Suitable pressure is provided by a spring bail, which holds the globe against the condenser opening. The globe seat, Fig. 7, and globe opening are carefully ground to insure a tight fit. The condenser, for which there is no occasion for removal unless for such repairs as would be attended to in the repair shop, is fastened very tightly by six machine screws against the base plate of the lamp.

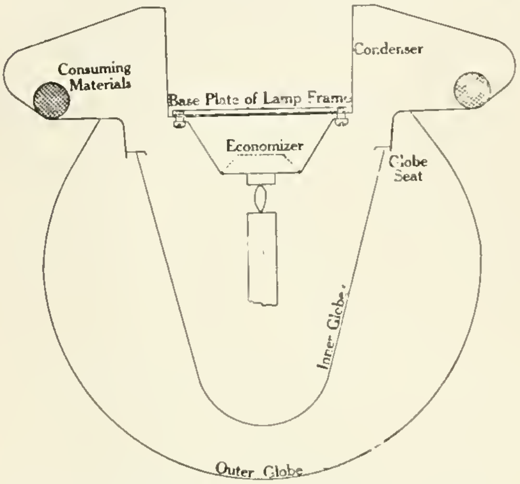


FIG. 7—DIAGRAM OF GLOBE, ARC CHAMBER AND CONDENSER

THE PROBLEM OF LIFE TESTING ELECTRIC INCANDESCENT LAMPS

H. S. DUNNING

THE aim of up-to-date manufacturing companies is to sell service. The time has passed when most manufactured articles can be sold by the glibness of the salesman or the appearance of the goods. The present day customer demands service from the article which he buys. The manufacturers have appreciated this and are making every effort to improve the quality of the service given by their goods. Perhaps in no other line has there been so much advancement in so short a time as in the field of illumination. Since so many installations for illumination are made up of electric incandescent lamps, the manufacturer of these lamps has been most energetic in analyzing and improving the quality of his service.

Investigation of the service given by the electric incandescent lamp is a complex problem. The customer who buys incandescent lamps is really buying a converter to change electrical energy into light. In buying such apparatus he is looking for a source of sufficient intensity for his needs and at the same time an apparatus which will be the most efficient as far as cost of energy and maintenance are concerned. There is no doubt that to many a life test means only the placing of a lamp in a receptacle and noting the number of hours which it burns. Perhaps from the point of view of the ordinary user, this idea ma ypartially be justified; from the viewpoint of the manufacturer, however, such procedure is practically worthless. The manufacturer must take into account not only the life to burn out of the lamp but he must also trace the change in candle-power throughout its life. He must study the effect on the lamp of burning it at various voltages and under varying conditions of voltage regulation. He must determine the most economical efficiency at which each of his various types of lamps should burn. In addition to this information, the manufacturer is vitally interested in data which is of no interest at all to the lamp user. This data which the manufacturer is searching for is that which will tell him what causes the failure of such lamps as may fail on test. In order to obtain this information, all of the larger manufacturers of incandescent lamps have installed well equipped testing departments. They are spending every year thousands of dollars in research and factory control work.

The testing work being done by the lamp manufacturers may roughly be divided into two parts, which can be called control work and development work. By control work is meant the work which every manufacturer must do in order to maintain uniform quality. The incandescent lamp is an apparatus which is extremely sensitive to small changes or differences in its construction. It is a highly scientific piece of apparatus manufactured in very large quantities and sold at a comparatively low cost. These conditions mean that the greatest care must be taken to prevent in any particular run of lamps what is commonly known as a "slump" in quality. To fully determine just what results will be obtained from an incandescent lamp, it is necessary to burn the lamp for a length of time which destroys its usefulness. It is, therefore, necessary for the manufacturer to rsort to sample testing. One of the first problems in life testing from the manufacturer's standpoint is the proper selection of samples. One test a month for instance may not represent adequately the condition of quality for the entire month. It is thought better practice to take a test of each of the more important types of lamps every week and average the results obtained for a monthly figure. The types of less importance are represented by the average results of two tests taken during the month. It is absolutely essential that these tests be taken at random and that when lamps are once chosen for life test, they must not be exchanged for other lamps. Further, it seems advisable that whenever a test gives poor results, more lamps should be taken immediately and an investigation started to determine the cause of the trouble. In cases where a serious drop in quality is found, thousands of lamps are sometimes held up awaiting the determination of their quality to see if it is satisfactory, before the lamps are shipped. The most careful sample testing which the manufacturer can make leaves much to be desired, even though hundreds of lamps are destroyed each month in testing. There is a great necessity for some test which can be applied to a lamp without injuring it, so that greater quantities of lamps may be tested and a more representative figure obtained. There is also a great need for a quick test to determine the cause of trouble.

There is a growing tendency among laboratories which make life tests to test lamps at very high efficiencies and to attempt to interpret the results so obtained into terms of life at normal efficiency. The lamp manufacturer places no confidence in these tests, although he is in perfect sympathy with the desire for quick results. If such a test can be found which is satisfactory, the manufacturer will unhesitatingly indorse it, since he is tremendously handicapped in his development and control work by the lack of a satisfactory test of this nature. A vast amount of work is being done by the lamp manufacturer to determine the characteristcs of his lamps before burning, while burning and after burning. This study is being made in an effort to find some characteristic or combination of characteristics which have a direct bearing on the value of the lamp and which will show at an early stage of the test what the ultimate service of the lamp will be.

To make even the most preliminary sort of life tests, the following things are absolutely necessary:—

1—A well drilled and efficient corps of operators and engineers.
2—Properly constructed and well equipped photometric appliances.
3—An equipment for burning lamps so arranged that the lamps may be burned at any desired voltage.
4—An extremely accurate voltage regulation for the burning racks.

These factors are practically of equal importance and the absence of any one of them will tremendously reduce the value of the test results. The importance of life testing is constantly increasing. It is probable that advanced manufacturing methods will do away with the commercial photometry of Mazda lamps, thereby throwing an increased amount of control work on the photometric and burning equipment of the laboratory. The introduction of means for preventing blackening and a further study of this means has greatly increased the amount of testing work. In addition to this, the ever increasing demands of users for a higher efficiency and the constant search of the manufacturer for improvements and for new lamp materials have kept the testing departments working at the point of maximum effort.

It is almost impossible to present adequately in a short article all of the problems faced by the manufacturer in his attempt to render service by an analysis of his product. Roughly expressed, his greatest needs at the present time are a quick means of obtaining accurate information as to the performance of his lamps and new kinds of apparatus with which he can accurately measure lamp characteristics.

POWER ANALYSIS OF A VENEER PLANT

C. W. DRAKE

VENEER suggests to most people a method of making a small amount of valuable wood cover a large surface. As a matter of fact a large amount of veneered stock is made, the actual cost of which is practically equal to that of the solid stock. The reason for its use is that panels can often be made up of three-ply veneer and filler, which is thinner and stronger and less likely to check than when made of one piece. In small boxes, chair seats, etc., lightness of weight and great strength can be secured by the use of built-up stock. In the manufacture of pyrographic and other art work, there is a large demand for blocks and panels of thin, clear grained bass and maple wood of various sizes and, to obtain the best results, made-up stock is generally used. Small fruit and berry baskets are made directly from a single thickness of veneered stock.

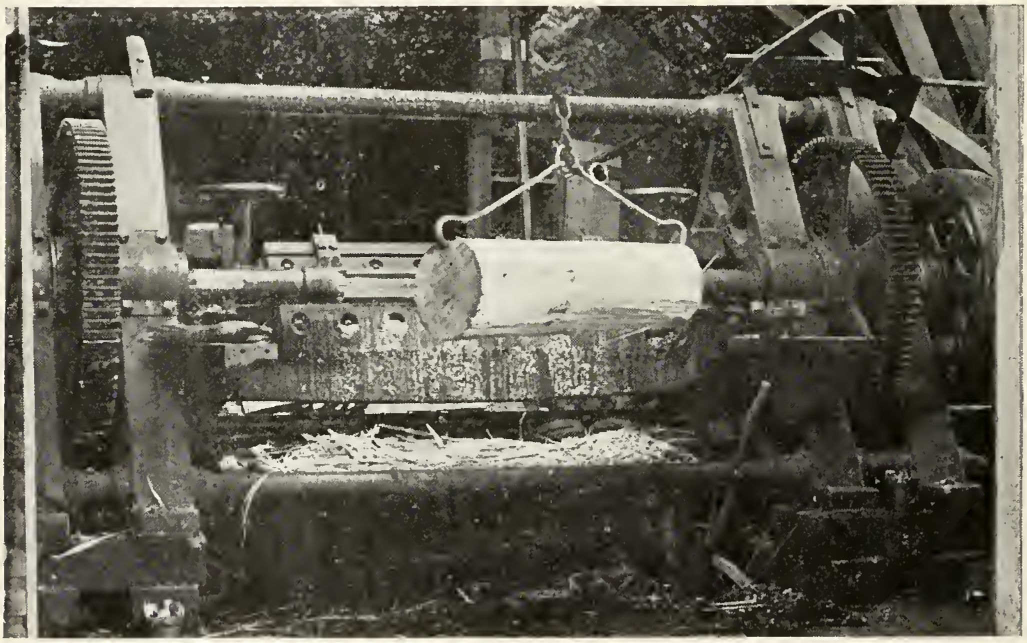


FIG. I—FRONT VIEW OF VENEER LATHE, WITH ROUGH LOG ABOUT TO BE SWUNG IN PLACE

In the manufacture of this stock, electricity plays a part similar to that in any wood-working plant, but there are a few applications entirely special to this industry. Principal among these is the veneer lathe itself. These are built in a large number of sizes, but probably the greater number in use take logs from four feet to six feet long. It is seldom possible to operate a lathe continuously, due to the time required to change bolts and cut the veneer, and since the lathe with its veneer clipper is usually remote from other machines, electric motor drive has proven very economical. The lathe is generally placed in close proximity to the soaking pits, where the blocks are soaked in hot water, although, in summer and with the softer woods, this process is often omitted. Due to the fact that a countershaft is usually required for the lathe, and also that the clipper is nearby and requires little power, it is usual practice to drive both from one motor belted to the countershaft.

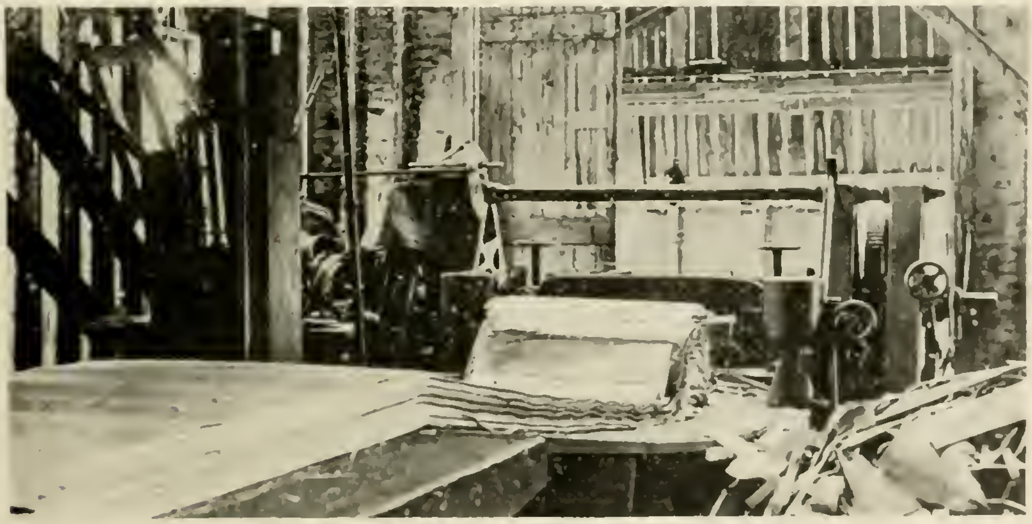


FIG. 2—REAR VIEW OF LATHE SHOWN IN FIG. 1 WITH VENEER DRAWN OUT READY FOR SLICING

Considering for a moment the operation of turning veneer from a log 15 inches in diameter, it will be seen that since the diameter of the log is constantly decreasing as the operation continues, if the speed at first is satisfactory, then as the diameter decreases, the speed and output decrease in direct proportion. Most lathes are driven by constant speed motors, and where group drive is used this is necessary. Squirrel cage motors are entirely satisfactory, as they are not required to start under load.. Where individual drive, with speed adjustable over a considerable range, is possible, such as can be secured by the use of a commutating pole direct-current motor, a considerable saving in time may be effected. Thus, if the cutting speed at the start is 200 feet per minute, then when the bolt is turned down to 7.5 inches diameter, the speed is only 100 feet per minute. The average speed is then 150 feet per minute, whereas if the cutting speed could be maintained at 200 feet per minute, by increasing the motor speed as the size of the bolt decreases, the cutting time would be reduced about one-third. The production would not be increased that amount, due to the time taken to change logs, but an increase of at least twenty percent might be expected. By using an individual motor for the lathe it is possible to so adjust the control that an approximately constant speed will be maintained as the diameter of the bolt is decreased.

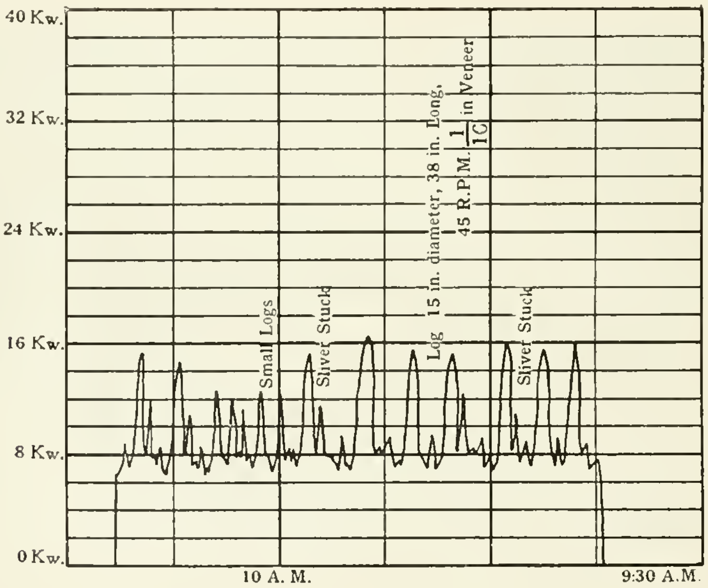


FIG. 3—LOAD DIAGRAM SHOWING PERFORMANCE OF 30 HORSE-POWER, 1 120 R.P.M. SQUIRREL CAGE MOTOR DRIVING 52-INCH VENEER LATHE AND VENEER CLIPPER

A typical veneer plant using electric motor drive is that of Gorham Bros. at Mt. Pleasant, Mich. Various kinds of veneer are made at this plant, but the greater portion is made up for pyrographic work, desk and furniture panels, etc. Electric motor drive is used throughout and has been found to be much more economical and satisfactory than the line shaft drive formerly used. A veneer lathe at this plant, with a rough log about to be put in place, is shown in Fig. 1, while a rear view of the same lathe is shown in Fig. 2, with veneer drawn out on the bench ready to be sliced on the clipper. The refuse at the side of the machine is used for fuel.

When machines are already driven by electric motors, their exact operating conditions can best be shown from an analysis of graphic meter records. The diagram in Fig. 3 shows the performance of the 30 hp, 1 120 r.p.m. induction motor, driving a Coe 52-inch veneer lathe and the veneer clipper. It will be seen that the friction load of the shafting and machine averages about eight kilowatts, and that when turning one-tenth inch veneer from the 38-inch green basswood logs the maximum power did not exceed 16 kilowatts. The lathe made 45 r.p.m., so that the actual cutting speed depends on the size of the log. The variation in shape and magnitude of the peaks is due to difference in diameter and condition of the logs, although all those cut were green and unsoaked. The maximum peaks are caused by logs 15 inches to 18 inches in diameter.

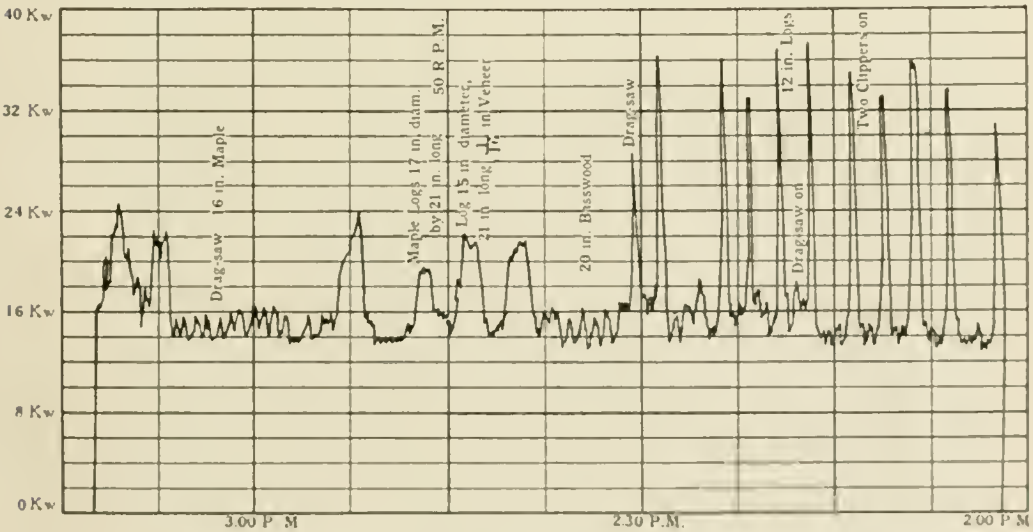


FIG. 4—GRAPHIC METER LOAD-RECORD FOR 50 HORSE-POWER, 1 120 R.P.M. INDUCTION MOTOR DRIVEN VENEERING EQUIPMENT

Fig. 4 shows the load of a 50 hp. 1 120 r.p.m. induction motor driving a group of machines consisting of a Coe 64-inch veneer lathe; two Coe 64-inch clippers; one Sturtevant 70-inch blower, 330 r.p.m., and one drag saw. The effect of the blower is simply to raise the friction load on the curve; the clipper load is almost negligible so that the load of the lathe and drag saw are easily separated. This lathe ran at 50 r.p.m. Maple logs were being turned, making three-sixteenths inch veneer from 36-inch logs, as shown at the right, and one-sixteenth inch veneer from 21 inch logs at the left of the curve. With the heavy veneer the power taken in the cut is about 24 kilowatts, while on the light cut it is about eight kilowatts.

With the thicker veneer, only a short time is taken to cut a log and the relative time of the two cuts is readily seen. The drag saw requires between two and three kilowatts and its load on 20-inch bass logs is also shown.

In a plant of this kind there is a large amount of wood refuse which is useful for fuel, and to reduce this to the proper size a Mitts & Merrill No. 2 hog blower is installed. This is driven by a 40 hp, 1 120 r.p.m. induction motor with double extended shaft, one belt driving the hog and one the blower, which conveys the chips to the boiler house. A test on this motor showed a load of 16 kilowatts running light (including blower), an average working load of 22 kilowatts and a maximum of 31 kilowatts.

A list of the motors installed and a brief description of the machines driven is given in Table I. Tests made on these motors show that all are of the correct size for the machines driven, although the 15 horse-power motor in the glue room is large enough for the addition of more machinery.

TABLE I—LIST OF MOTORS AND DRIVEN MACHINES.

Motor		Machines Driven
H-P	R.P.M.	
50	1 120	Bolt saw, swing saw, planer, etc.
50	1 120	Planing mill, planers and matchers, moulders, etc.
50	1 120	64-inch veneer lathe, clipper and blower.
50	1 120	Three 52-inch drum sanders and one belt sander.
40	1 120	Hog and blower.
40	1 120	Allington & Curtis No. 16 double blower.
40	850	64-inch veneer lathe and clipper.
30	1 120	Five equalizing saws.
30	1 120	52-inch veneer lathe and clipper.
30	1 120	Group in center-stock room, saws, surfacers, etc.
25	1 700	Sturtevant 33-inch blower.
15	1 120	Glue room, presses, spreaders, elevator, etc.
7.5	1 120	Machine shop.
7.5	1 120	American blower, 70-inch steel plate fan.
3	1 700	Coupled to Brooks No. 1 centrifugal pump.
468	Total Horsepower Installed.	

SAFEGUARDING MOTOR-DRIVEN APPARATUS

D. C. PULTNEY

This article deals especially with methods of safeguarding machinery which is direct driven by electric motors. In the majority of instances the safeguarding has been applied to the electrical parts as well as to the points of mechanical danger. All the safeguarded devices illustrated herein have been constructed at the factory in which they are installed, and are comparatively inexpensive and of simple construction. The article may be considered as a continuation of the author's article on the same general subject in the JOURNAL for July, 1912. (Ed.)

IT HAS BEEN the repeated observation of those having charge of workmen that it is frequently impossible to get the average man to take the most obvious precautions to prevent accident to himself or to his fellow employees. In fact, it is almost always easier to get a man to assume risks in furthering his work than it is to get him to use a safety device. This seems to be especially true of electrical apparatus, which on account of its quiet and steady operation is frequently treated with the grossest carelessness. Hence in order to prevent accidents from contact with live electric conductors, moving gears, belts, etc., it is necessary to screen all such parts carefully so that accidental contact is practically impossible.

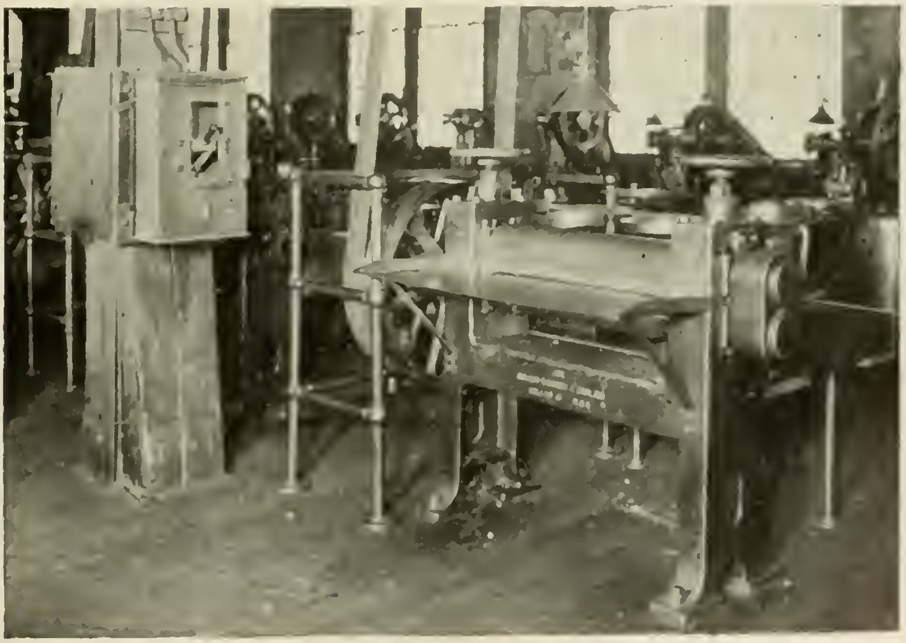


FIG. 1—SAFEGUARDED FLATTENING ROLLS IN A LARGE PUNCH SHOP

To design and install safeguarding devices properly, requires a thorough knowledge of the operation of the tool or apparatus, both in its normal operation and under abnormal conditions. Thus, there is always the possibility of accident from a piece of scrap metal being caught in the spokes of a revolving pulley, and such possibilities should be as carefully guarded against as actual contact on the part of the workman with the pulley or gear wheel. Even with the most careful safeguarding, conditions arise which cannot be foreseen, and these must be considered as hazards of manufacture. There is, however, a growing tendency among manufacturers to use every possible precaution to minimize such hazards.

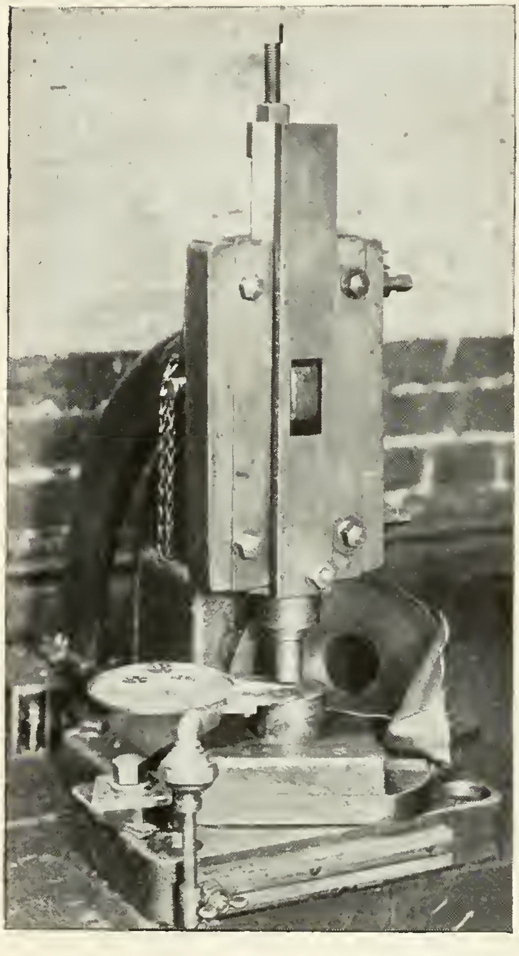


FIG. 2—SMALL KICK PRESS EQUIPPED WITH PNEUMATIC BLOWER FOR REMOVING PUNCHINGS

In a previous article, the writer described a number of safety devices which have been installed in the works with which he is connected. The photographs which are here reproduced illustrate various additional devices, of a type which should be applicable in any large factory.

In Fig 1 is shown a pair of flattening rolls through which thin sheet steel punchings, such as armature cores and transformer iron, are run in order to remove the burr at the edges and make them stack evenly. The operator sits in front of the machine and feeds the material into the rolls through a narrow slit, the piece being caught by the revolving rolls underneath the circular guard and ejected onto the table on the other side of the machine. The guard positively prevents any danger of the operator's fingers being caught in the rolls. There is also a double cap on the end of the rolls. The belt is protected by a gas pipe fence, and the switch on the adjoining column, controlling the motor, which is mounted on the ceiling, is covered completely, only the switch handle projecting far enough to allow the operation of the switch.

In feeding small parts into a press, and especially in removing them again, there is great danger of crushing the fingers. In Fig. 2 is shown a method of eliminating this possibility. This type of press is known as a "kick press", operated by the pressure of the foot on a treadle. A shallow pan at the left holds a number of small punchings which are fed to the die one at a time, the operator using a small stick or picker to place the punching in position. In front of the press is a compressed air pipe with nozzle attached. The operator feeds in a punching, presses on the treadle and the die descends, flattening the punching. On the return of the die, a valve is opened automatically and the air blows the punching into the hopper at the rear, whence it falls into a pan under the bench. There is thus no occasion for the operator to have his fingers near the die at any time.

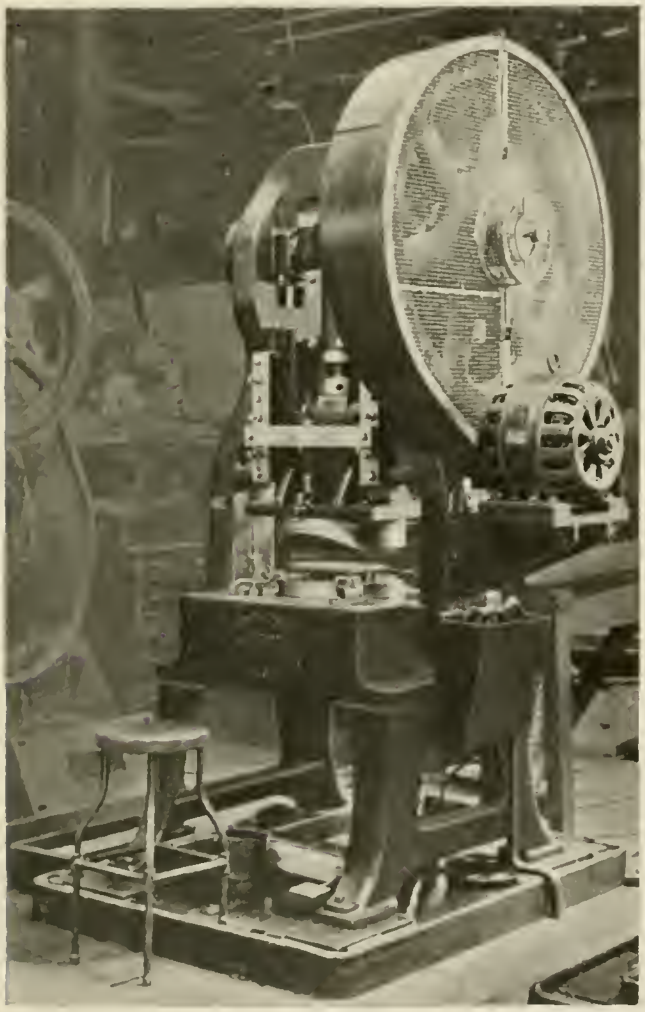


FIG. 3—COMPLETELY GUARDED PUNCH PRESS

A larger punch press is shown in Fig. 3. In this case the guard completely covers both the large and small gear, while the switch controlling the motor, and located immediately under it, is completely enclosed in a compressed fibre insulating box from which only the handle projects. This is one of a number of presses which are thus completely guarded. The material is fed into these presses by means of a small pneumatic finger which prevents the possibility of the hand being caught under the die.*

A row of automatic notching presses for cutting armature punchings is shown completely safeguarded in Fig. 4, each of the presses being driven by an individual motor. There is really small danger of accident near one of these presses because the workman sits in front of the press and should have no occasion for coming into contact with either the dies or the belt, but it was considered advisable to eliminate any possible chance of injury.

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*See article on "Safeguarded Factory Devices and Equipment" by the author in the JOURNAL for July, 1912, page 603.

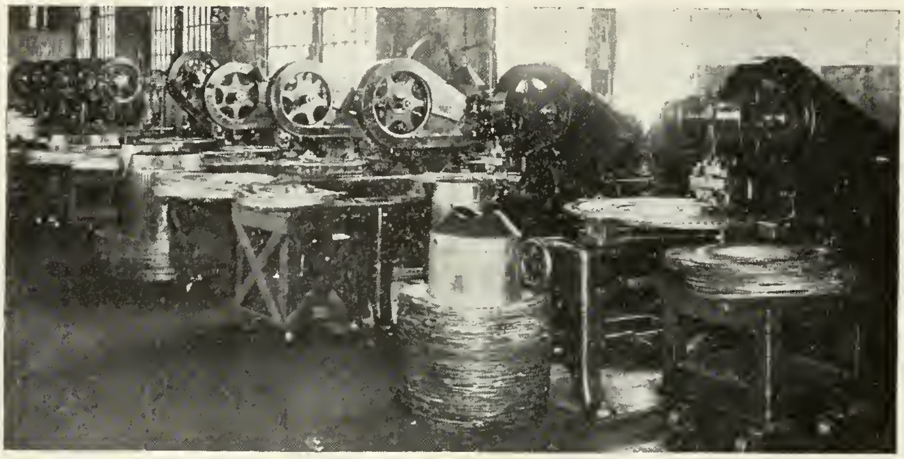

FIG. 4—ROW OF AUTOMATIC NOTCHING PRESSES, WITH DRIVING BELTS AND FLYWHEELS COVERED

In Fig. 5 is shown an example of three very dangerous winding machines most completely safeguarded. In the machine in the foreground can be noticed the spring hinged doors, all open to admit ready access to gears and clutches for oiling or inspection, the doors on the machines in the rear being shown in the closed position. One point to be watched in the mechanical method of

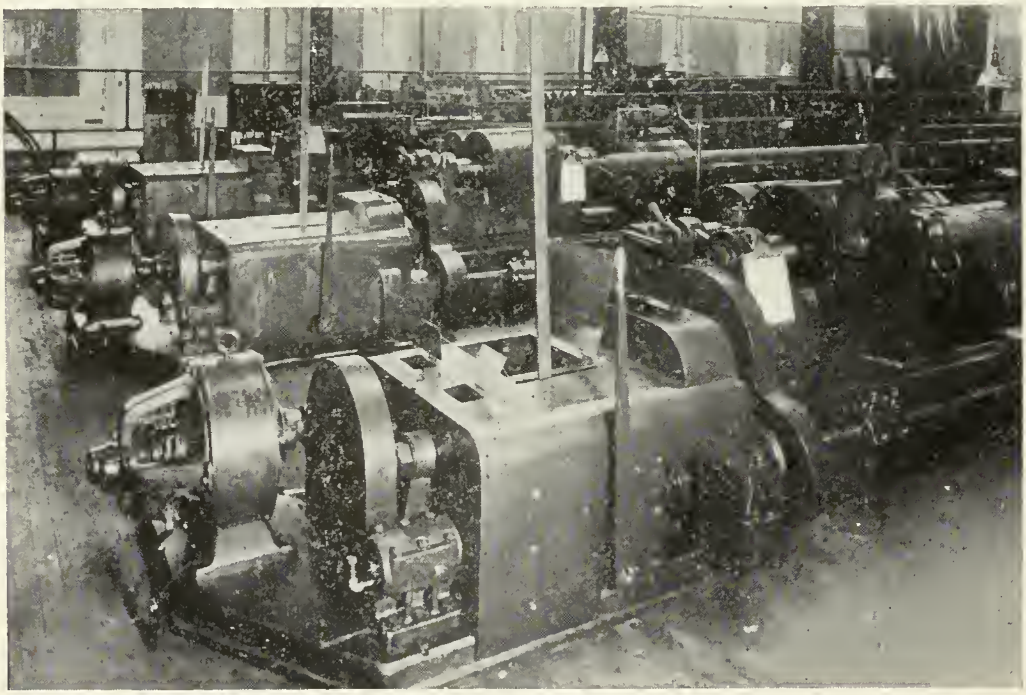

FIG. 5—GROUP OF SPECIAL WINDING LATHES WITH REDUCTION GEARS AND CLUTCHES COMPLETELY SAFEGUARDED

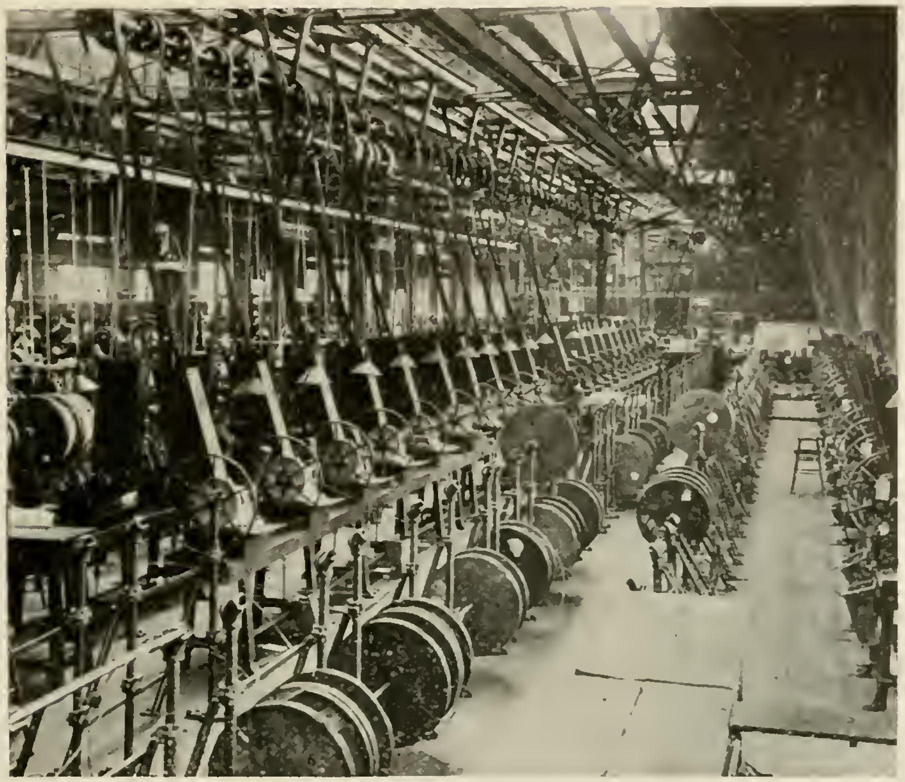

FIG. 6—WINDING LATHES FOR SMALL FIELD AND ARMATURE COILS
Gears and belts safeguarded.

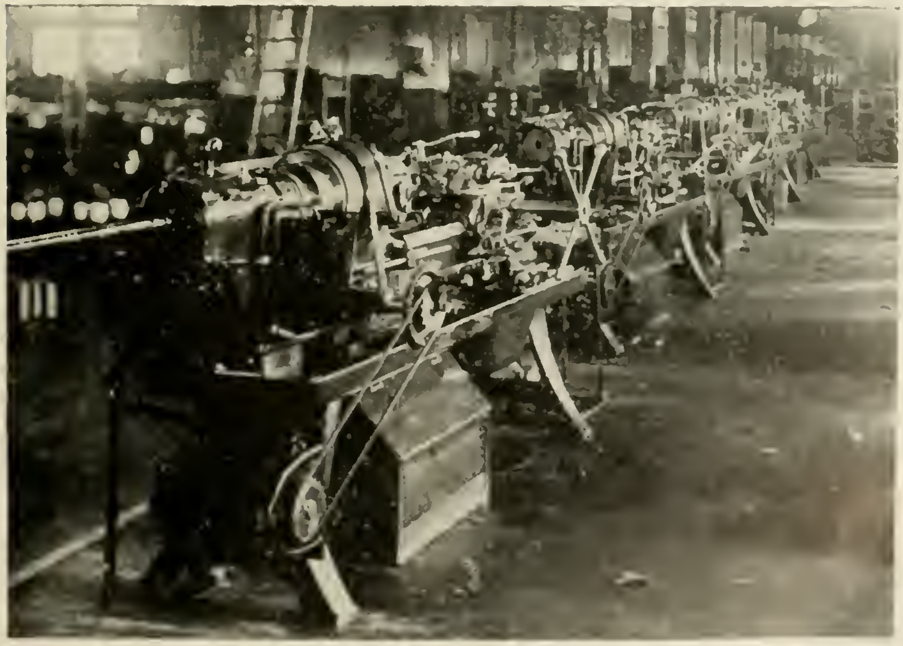

FIG. 7—ROW OF INDIVIDUALLY MOTOR-OPERATED TURRET HEAD SCREW MACHINES

Motor, control and transmission completely safeguarded. The sprocket chain shown in the foreground runs from the motor controller to the control handle. It is consequently hand operated and runs at very slow speed, and very intermittently. Hence there is no necessity for covering it.

safeguarding machinery is to prevent, if possible, the removing of a guard for any purpose whatever. In many instances, serious accidents have happened through the neglect to replace guards which were removed for inspection or some other legitimate purpose. The spring hinge doors cannot possibly be left open, unless they are deliberately tied or propped open, as was done when taking the photograph. These guards are of heavy sheet steel, riveted to a frame work of angle-iron, and held in place by machine screws.

Small winding lathes have been in the past a prolific source of trivial accidents. Four rows of such lathes are shown in Fig. 6, completely safeguarded both with respect to the belts and the gears, so that at the present time it is only by some very unusual combinations of circumstnces that accidents happen on these lathes. The unguarded spoke wheel on each lathe operates at a comparatively slow speed, and is used for turning the lathe by hand when desired. As it is perfectly smooth, there is no danger of a garment being caught.

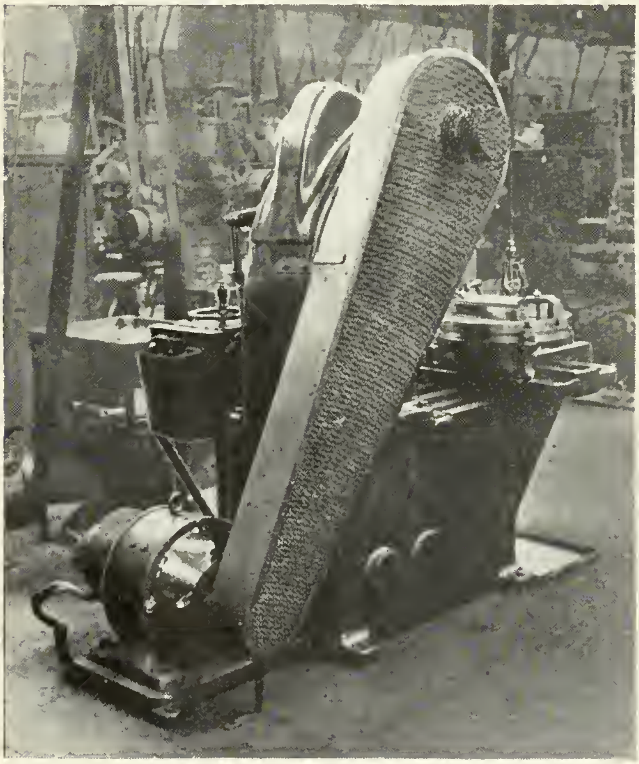
FIG. 8—SMALL SLOTTING MACHINE WITH BELT AND SWITCH SAFEGUARDED

A row of motor-operated screw machines is shown in Fig. 7, in which the motor and transmission are completely enclosed by a screen of woven wire on an angle-iron frame work. A lid on each side of the machine permits ready access to the bearings and brushes for oiling or inspection. All the wiring is enclosed in conduit and the switch blades are covered with a compressed fibre box from which the switch handle is seen projecting. An adjustable speed motor is provided, thus doing away with the necessity for changing gears, although back gears are provided for wide variations in speed, and are completely covered.

A very neat and efficient belt guard, covering a belt which was at the side of a main aisle near which workmen were continually passing, is shown in Fig. 8. This guard was put in place to protect passersby, rather than the operator of the machine. A switch guard is shown on the controller in the rear. A similar type of guard for a belt driving a line shafting is shown in Fig. 9, this belt being also located adjacent to an aisle where workmen were continually passing. The motor and switch box, immediately behind the belt, are also completely enclosed. The belt guard is built of heavy angle and sheet steel, the sides being filled in with expanded metal. This combination of sheet steel and expanded metal makes a very strong and neat looking safeguard and takes up very little room. Another example of this type of guard protecting the main driving belt of a planer is shown in Fig. 10. This is a guard of unusually large size, and is very strong and efficient. It is strengthened across the expanded metal by two strap braces which tend to make it very rigid. Any of these guards can be removed in a short time when necessary to make any repairs or adjustments.

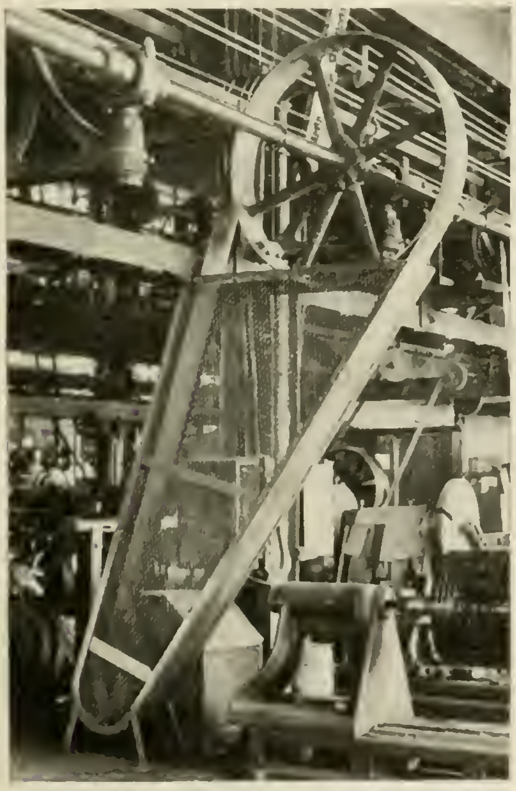

FIG. 9—GUARD FOR BELT ALONGSIDE MAIN AISLE

Ordinarily only power driven apparatus needs to be safeguarded. A portable hand crane, however, forms an exception, as a heavy casting may cause the gears to rotate contrary to the operator's will. In Fig. 11 is shown a crane of this type used for conveying small castings where an overhead crane cannot be used, and it has seemed advisable in this case to cover the gears to prevent any possibility of a man's finger or hand being caught.

A number of schemes of enclosing switches to prevent accidental contact with the live parts have been devised. A very satisfactory form is located at the left of Fig. 1. These guards are made of expanded metal or heavy wire screen with angle iron frame work. Still another type is shown in Fig. 12. In both of these types the guard is a fixture and is not removed except for repairs. Ready access to the switch handle is allowed, without any possibility of accidental contact with live parts. The handles on the double-throw switches shown in Fig 12 are removable, thus preventing any operation of the switches by unauthorized persons. Still another method of accomplishing the same purpose is shown in Fig. 13, in which the door on the front must be unlocked and opened before the switch can be operated, keys being held only by the foreman and certain authorized workmen. At the rear of the switch can be seen a board of heavy insulating material which is carried around the back of all of these guards so as to completely close in all the openings between the box and the column, thus preventing any possibility of a workman receiving a shock in case of any contact with live parts, as would be possible if this covering were of iron, by making metallic contact with an iron column.

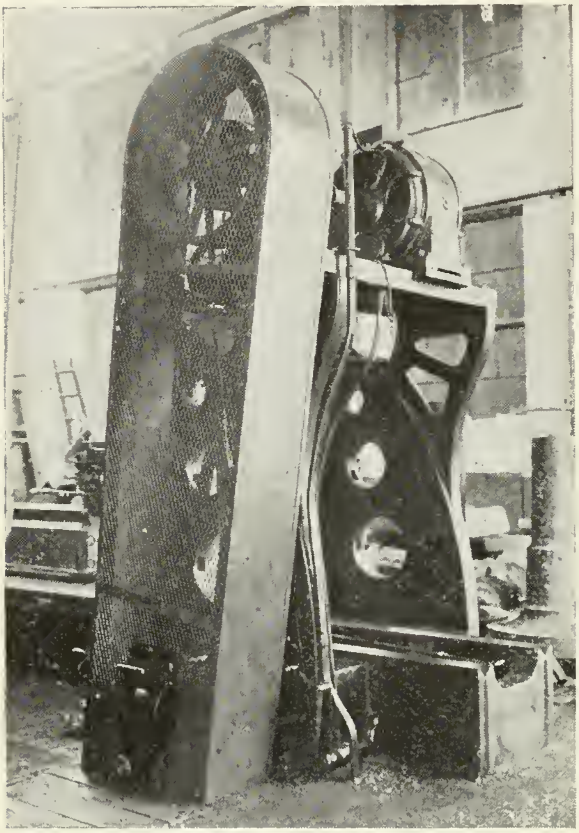

FIG. 10—SAFEGUARDED PLANER BELT

Accidents by machinery comprise by no means all of the possibilities for acidents around a large manufacturing concern. A heavy glass reflector used in connection with modern tungsten illumination systems can cause severe injury if broken and pieces al-

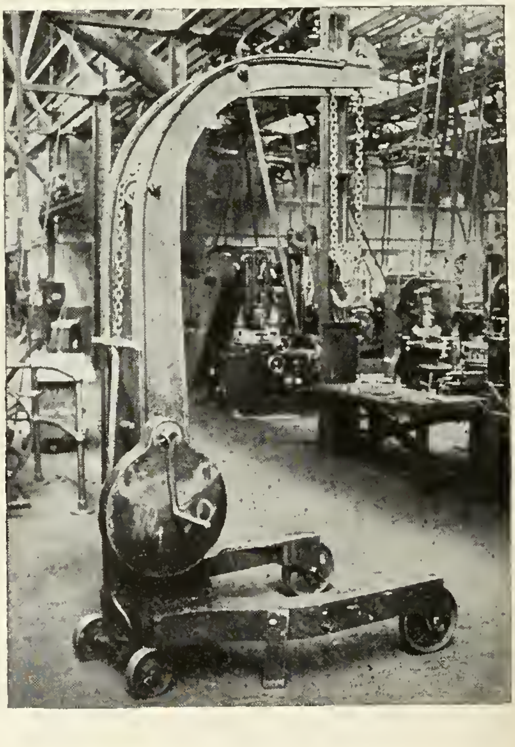

FIG. 11—SAFEGUARDED PORTABLE FLOOR CRANE

lowed to fall on the workmen, hence all reflectors above a certain size are covered with a mesh of copper wire as shown in Fig. 14 as soon as received at the lamp department. This mesh is placed both inside and outside of the reflector and is fastened to the holder as shown. The reflector shown at the left was shattered by an explosion of an air tank, but as can be seen the wire safeguard retained the broken glass. The one at the right was suspended over an aisle where workmen were passing constantly, and was found to be in this cracked condition by a lamp inspector in going his rounds. This is a very cheap and efficient method of safeguarding ceiling lamps and should be applied wherever possible as a reflector would need to be shattered into very small pieces before it would drop to the floor.

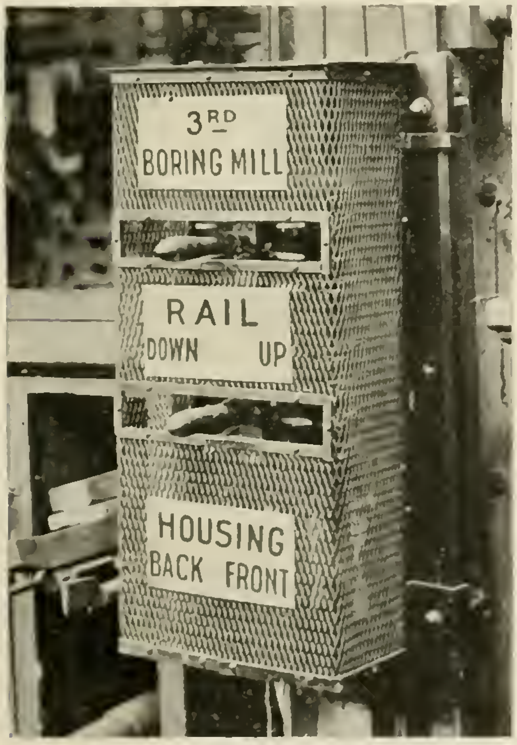

FIG. 12—SWITCH BOX COVERING TWO DOUBLE THROW, FOUR POLE SWITCHES

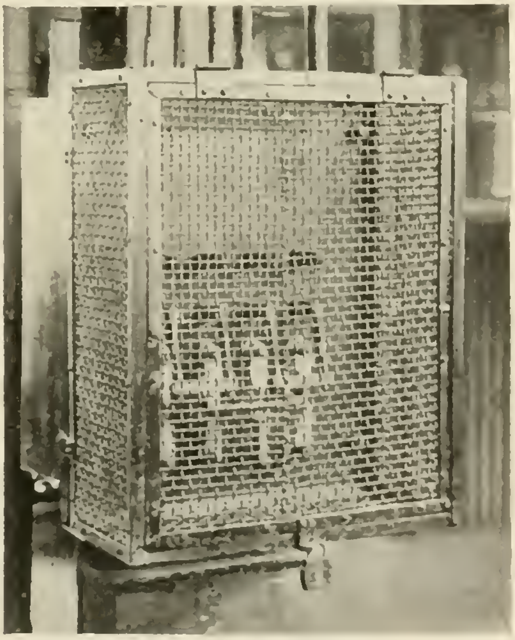

FIG. 13—SWITCH BOX FOR COMPLETELY ENCLOSING A SWITCH AND PREVENTING TAMPERING BY UNAUTHORIZED PERSONS

A type of safety gasoline and oil-can which is quite extensively used is shown in Fig. 15. The principle of the device is that of the "Davy Mine Safety Lamp", and the fine mesh of the screen shown at the left prevents any possibility of explosion due to the ignition of escaping vapors. This safety device is a part of the can as purchased, but the wooden lagging is placed around the can at the factory as an additional precaution to prevent damage.

The foregoing are a few examples of what is being done throughout one large factory along the line of safeguarding dangerous pieces of mechanism. Securing safety for employes is a gigantic problem and one difficult to handle, but one encouraging feature is the gradually diminishing opposition on the part of the workmen. As they come to see that the great object is their safety and the betterment of their working conditions, and that their production and wages are not decreased, they are beginning to assist in the work. In fact, the workmen's part in the prevention of accident is one of the greatest importance. He must get rid of the habits of carelessness and acquire the habit of looking out not only for his own safety, but for that of his fellow workmen., before any real advance can be accomplished. The expression is often held that everything should be made "fool proof", but it is not the fool that gets hurt every time; the wise man sometimes meets with injury at a time when his mind has become occupied on some other subject. "It is better to be careful than to be a cripple; rather cause a delay than cause an accident". The manufacturer has an opportunity to recover his financial loss, but the workman can never secure a new finger or a new hand. The slogan "Safety First" is a good one and should be impressed on every workman's mind.

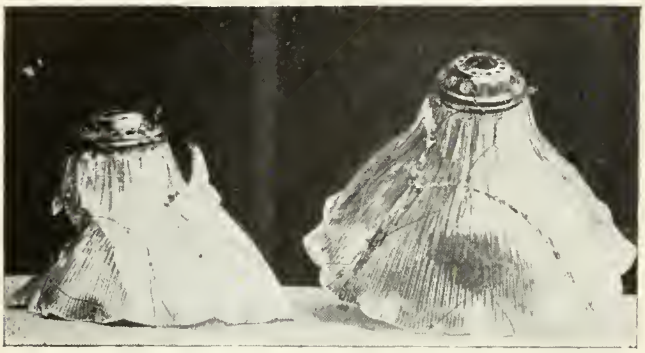

FIG. 14—WIRE MESH FOR PROTECTING BROKEN GLASS REFLECTORS FOR TUNGSTEN LAMPS

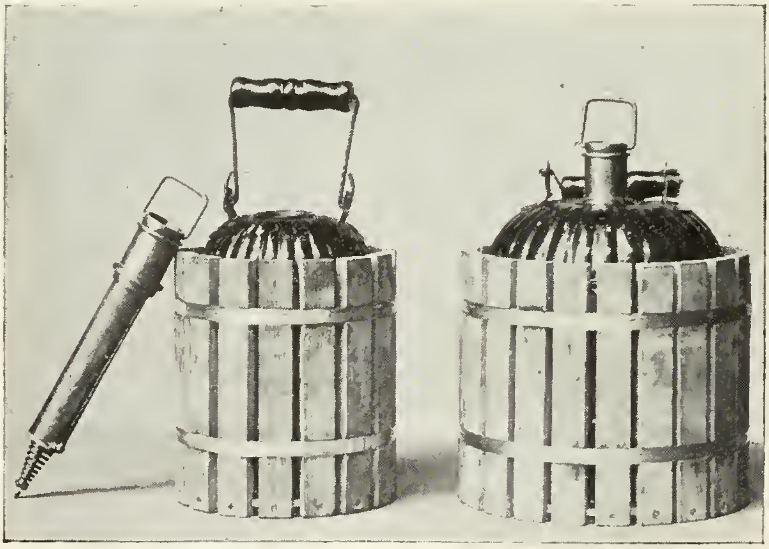

FIG. 15—SAFETY GASOLINE CANS

METHODS OF DETERMINING SHOP COSTS*

H. F. MacLANE

Cost Department, Westinghouse Electric & Mfg. Company

DURING the last few years the increased search for cost knowledge and the increased interest taken in the subject by manufacturers and by all kinds of business men have greatly exceeded that in any other phase of management. Production output, supervision of workmen and operation of machinery have always received the manager's attention and, generally speaking, he formerly considered costs as a subject of little interest to him and rather a matter that should be attended to by the accounting department. But today there is no manager worthy of the title who is not as anxiously interested in his costs as in any other part of his work, and in measuring the elements of his management (the production output, labor efficiency, machinery operation) the basis is calculated on the *cost* of the output, on the *cost* of the labor, etc. Of course, all managers can not be cost experts, but they can and do appreciate the importance of this part of their management and employ accounting experts to handle the work, they themselves understanding what results are required and being sufficiently conversant with the matter to know when they are getting what they require.

It is not the manager only who must appreciate the importance of costs. For example, the best salesmen can explain intelligently why the goods made by his concern should cost more than a competitor's; that his company uses material of such a grade at such a cost compared with the cheaper material used by the competitor; that the labor cost is higher on account of the skilled workmen employed who turn out only the best and most reliable class of work; that the higher overhead or indirect cost is due to many superior features that are of benefit to both the manufacturer and the customer, such as rigid inspection to insure against defects, special care in shipping to insure safe and prompt receipt, etc.

COST FIGURING

The following explanation will deal principally with cost figuring, which is interpreting that part of cost keeping which deals simply with compiling the cost of apparatus manufactured. In Fig. 1 are shown the definite steps in figuring costs of apparatus manufactured. The dark spaces represent the definite elements that have to be considered, and the blank or white spaces show the results secured by the addition of each of these items, that is, the different stages in arriving at the complete cost and selling price. By adding together the direct material and the direct labor the prime or direct cost is obtained. By adding to this prime cost the expense of operating the plant, the factory cost or the cost of manufacturing complete and storing or shipping is secured. By adding the selling and administration cost to the factory cost the total or commercial cost results. The selling price is determined by adding to the commercial cost the desired percentage of profit this being shown as the fifth and last item.

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*This is the third of a series of articles on Works Management.

The manager of a concern is vitally interested in each of the cost elements; but in plants where there is a separate manager or superintendent in charge of manufacture, he is, of course, more particularly concerned about factory costs. This cost is made up of three parts: the direct material, the direct labor and the indirect expense. In some concerns the factory cost is divided into four parts, the indirect material and indirect labor being kept separate the same as are the direct material and direct labor. Other companies make various other divisions of the cost figures, depending upon the decision of the management and sometimes also upon the nature of the apparatus manufactured.

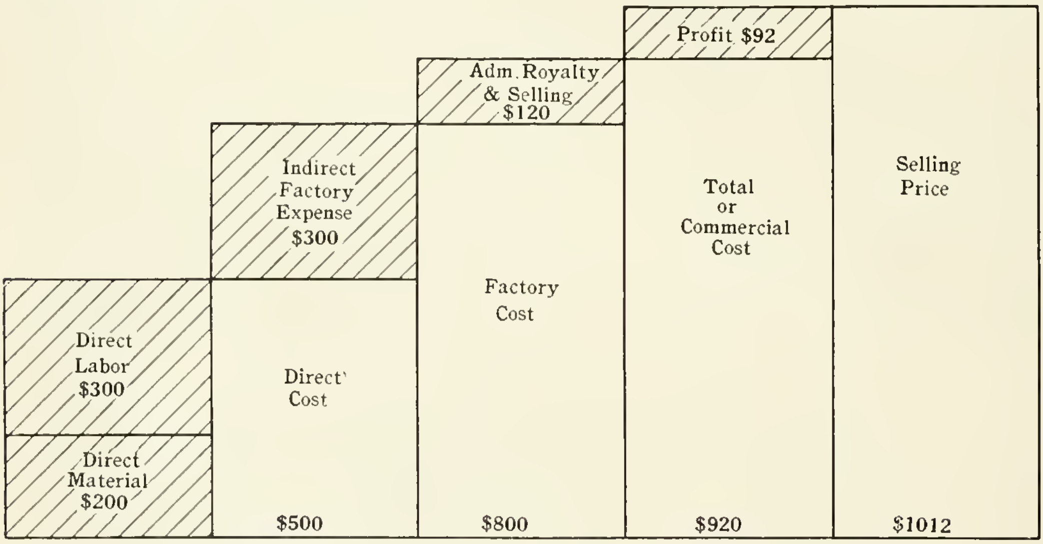


FIG. I—TYPICAL DISTRIBUTION OF COSTS IN A LARGE FACTORY

MATERIAL COST

Referring to the first shaded space, Fig. 1, the manner of arriving at the material cost is comparatively simple. The material used in making a piece of apparatus is included in the cost of the part at the same value at which it is bought from the out-former they are included in the material cost of the transformer side. For example, if porcelain insulators are used on a trans- at the same price at which they are purchased from the pottery. Cost material is thus considered as the price paid for material bought outside whether the material is raw or finished; that is, the material may have had labor performed on it.

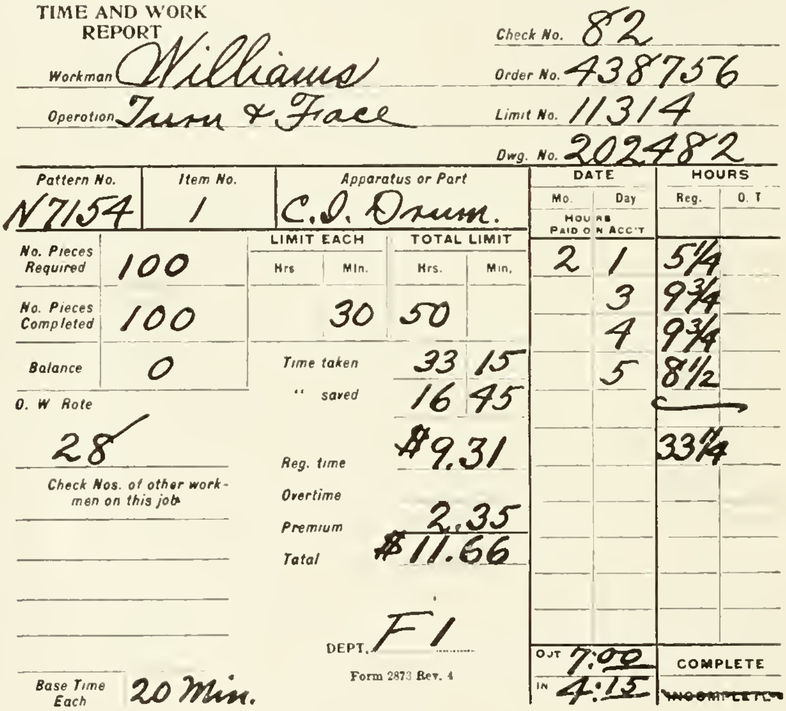
Under a departmental accounting system labor may be considered as material cost under certain conditions. This is when one department makes a part which is later assembled in another section to which it is sold the same as if from the outside. Aside from the fact that it would not be correct to include the original labor a second time in the labor cost, there is another and very important reason why this first labor is considered material when compiling the cost at the time the part is used in assembling it later on, and that is, because in determining the amount of indirect expense to be included in the cost of a piece of apparatus a certain *percentage* of the direct labor is added, and it will be readily seen that if labor on which this expense had once before been added were to be again included as labor it would result in too large an amount being included in the factory cost for indirect expense. For example, if a punch shop section makes some punchings and sells them to a railway section at a cost which includes the amount paid for the material, the labor in making the punchings and a certain percentage of this labor, which is considered sufficient to cover the indirect expense in the punchings section it would be just the same as if they had been bought from some outside concern, and the amount charged for the punchings would be considered material value, and the labor on which a percentage would be added to cover the indirect expense in the railway section would be only the labor in the latter section in building the motor.

However, when an analysis is to be made of the cost of the complete motor, the total actual material cost and total actual labor cost should be shown for each section, together with the total amount included for indirect expense; that is, so much material, labor and expense in the railway section. So that in the final analysis the exact total cost of labor and material can be set out separately.

Another feature to be considered when machining raw material, for instance, is whether the value of the scrap is worth considering. Take a brass or bronze end plate which, finished, weighs 50 lbs., but which before machining weighed 90 lbs. Then, either from the outside or from a brass foundry section 90 lbs. of raw brass was purchased at 18c a pound; therefore, were the scrap not to be considered, the material cost of the end plate would be $16.20. But, in addition to the finished 50-pound end plate, 40 pounds of scrap brass remain, and this scrap brass can be sold for 10c a pound or $4.00. Therefore, the material value is not $16.20 but $12.20. So where any value is attached to the scrap made in machining material, the value of machined material is the original cost less the value of this scrap.

LABOR COST

Like the material cost, the labor cost of an article can be determined definitely under most wage plans. However, the direct labor cost is not so easily determined as the direct material cost; and the degree of difficulty encountered depends very largely upon the particular wage system in use. The correct labor cost is obtained by having each workman report on a separate time slip, as shown in Fig. 2, the actual time put in on each job. Each slip is figured and posted to a labor record, Fig. 3, divided as to order numbers. When the order is finished, either the time slips, or duplicates of them or the labor record to which the time slips were posted, are checked with the record showing the operations required, to see that there is a record of labor on all these operations for each piece on the order. The total thus obtained is taken



TIME AND WORK REPORT

Check No. 82

Workman Williams

Order No. 438756

Operotion Turn & Face

Limit No. 11314

Dwg. No. 202482

Pattern No.	Item No.	Apparatus or Part
N7154	1	C.I. Drum.

No. Pieces Required	100
No. Pieces Completed	100
Balance	0

LIMIT EACH Hrs	LIMIT EACH Min.	TOTAL LIMIT Hrs.	TOTAL LIMIT Min.
	30	50	

	Hrs.	Min.
Time taken	33	15
" saved	16	45

O. W Rote 28

Check Nos. of other workmen on this job

Reg. time $9.31

Overtime

Premium 2.35

Tatal $11.66

DEPT. F1

Form 2873 Rev. 4

Base Time Each 20 Min.

DATE Mo.	DATE Day	HOURS Reg.	HOURS O. T
Hours Paid on Acc't			
2	1	5¼	
	3	9¾	
	4	9¾	
	5	8½	
		33¼	

OUT 7:00

IN 4:15

COMPLETE

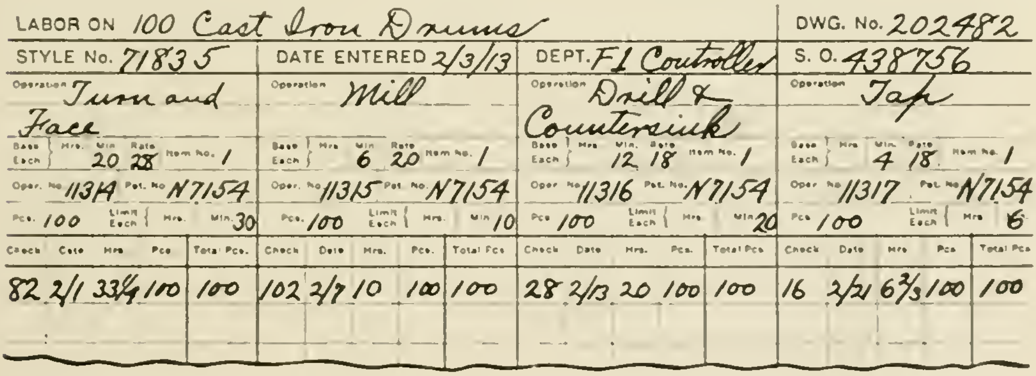
~~INCOMPLETE~~

FIG. 2—SAMPLE TIME SHEET

as the actual labor cost of the order or of the apparatus. In order to make sure that the correct labor cost is secured on each order a check is made to see that the total amount of the payroll of all check employees in each department agrees with the total of the direct labor record on orders in that department, as determined by the plan described above, plus the total labor charged to indirect expense.

It is especially important that the correct direct labor cost be obtained in every case, as the indirect cost of manufacturing an article, under some plans, is arbitrarily determined by adding a percentage of the direct labor cost, so that each mistake in the direct labor figures is multiplied in arriving at the total cost.

For example, the direct labor cost of a generator is found to be $200, and for each dollar spent for labor in that section two dollars are spent for expense, in other words, expense is running 200 percent of direct labor. Therefore, the indirect cost of the generator is $400. Now, assume that the material cost is $200, and a total or factory cost of $800 results. But suppose by mistake $50 has been omitted in totaling the direct labor from the labor records; this means that the indirect expense is out twice this amount or $100, the total amount out in the factory cost thus being $150. To show that the seriousness does not stop here assume that the sales department adds 15 percent to the factory cost to determine the commercial cost, and that to the commercial cost 10 percent is added for profit in arriving at the selling price. As the factory cost was $150 low, 15 percent of $150, or $22.50 is lost in determining the commercial cost, so that at this stage the figures are incorrect to the extent of $172.50. In the same way 10 percent profit on $172.50 or $17.25 is lost, and this means that the selling price is $189.75 low—all because the direct labor was



LABOR ON 100 Cast Iron Drums — DWG. No. 202482

STYLE No. 71835	DATE ENTERED 2/3/13	DEPT. F1 Controller	S. O. 438756
Operation Turn and Face	Operation Mill	Operation Drill & Countersink	Operation Tap
Base Each Hrs. Min 20 Rate 28 Item No. 1	Base Each Hrs. Min 6 Rate 20 Item No. 1	Base Each Hrs. Min. 12 Rate 18 Item No. 1	Base Each Hrs. Min. 4 Rate 18 Item No. 1
Oper. No. 11314 Pat. No. N7154	Oper. No. 11315 Pat. No. N7154	Oper. No. 11316 Pat. No. N7154	Oper. No. 11317 Pat. No. N7154
Pcs. 100 Limit Each Hrs. Min. 30	Pcs. 100 Limit Each Hrs. Min. 10	Pcs. 100 Limit Each Hrs. Min. 20	Pcs. 100 Limit Each Hrs. 6

Check	Date	Hrs.	Pcs.	Total Pcs.	Check	Date	Hrs.	Pcs.	Total Pcs.	Check	Date	Hrs.	Pcs.	Total Pcs.	Check	Date	Hrs.	Pcs.	Total Pcs.
82	2/1	33¼	100	100	102	2/7	10	100	100	28	2/13	20	100	100	16	2/21	6⅔	100	100

FIG. 3—SAMPLE LABOR RECORD CARD

out $50 in the first place. Moreover a cost once worked up will often be used for all machines of this particular type delivered for six months or a year, so that correct labor costs are extremely important.

INDIRECT FACTORY EXPENSE

The third block in Fig. 1, and the last step in arriving at the factory cost, is the indirect expense. This is also known as overhead, burden, etc. Indirect expense includes every expense after those for the direct labor and material, required to produce an article, such as the pay of foremen, clerks, inspectors and others, taxes, rent, heat, light, handling material, cleaning factory, cost of buildings, repairs to buildings, depreciation in the value of buildings, and, in the same way, the cost, repairs and depreciation of tools and machinery, power for operating machines, defective design, labor and material, loss on surplus material scrapped, etc. Some concerns charge into this indirect expense the interest on the amount invested in equipment, product, etc.

The direct labor cost plan of distributing indirect expenses is about the simplest method but it is considered somewhat less accurate than some of the other plans. Some of the other methods of distributing indirect expense are:—direct labor hours, direct labor and material, old machine rate, new machine rate, fixed machine rate and new pay rate.

There is one method of distributing indirect expenses that, for a better name, is sometimes referred to as the "blanket" plan, which some small manufacturers use, but writers on costkeeping do not often include this in naming methods for distributing expense. Under this plan the manufacturer will total all his expenses during the year, except his labor and material, and divide this figure by his total sales during the year to find the ratio of the total expense to the total sales. This ratio is used throughout the next year on all articles sold, regardless of the actual conditions or variations.

The direct labor cost plan provides for adding a certain percentage to the direct labor cost of an article to ascertain the indirect expense of making the article; this percentage being arrived at by finding the relation of the total factory expense to the total direct labor. An improvement on the blanket plan is to determine as closely as possible the relation of the expense to direct labor by sections and to check up these figures monthly. In one large plant, the relation of the expense to the direct labor is determined by works sections, and, in some cases, by sub-departments; and these figures are checked up monthly. In order to determine as nearly as possible the expense chargeable to each section, these expenses are divided into three classes: Class "A," those that can be fairly, accurately allocated to individual sub-departments of a section; Class "B," those that can be assigned to certain sections; and Class "C," those expenses that come under the head of general and which apply to the factory as a whole (taxes, storekeeping, etc.) These last are distributed to the different setions as equitably as possible, the conditions and circumstances in conection with each kind of expense being taken into consideration in making the distribution.

Perhaps this can be made a little plainer by an example. Assume that the direct labor in department "Z" during a certain month is $4 000 as obtained from the semi-monthly payroll of check men by deducting the amount paid check men for expense labor. During this same month the expense chargeable to the department "Z" amounts to $6,000; this amount includes such Class "A" and Class "B" expenses as the pay of men handling material, the pay of clerks, foremen and others working in the section, the loss due to defective workmanship and defective material, the cost of new small tools, the repairs to tools already in the section and other such direct expenses charged to or incurred by the section during the month; and also includes the section's share of Class "C" expenses that are genral expenses and that have to be divided among the different sections as correctly as possible, such as the cost of watchmen, expense of fire brigade, operation and maintenance of industrial railways, salaries of paymaster, storekeeping expense, expense of the shipping department, and other general charges. In this way it is found that the expense of the section during the month was $6 000 compared to $4 000 productive labor, or, in other words, the total indirect expense during the month equalled 150 percent of the total direct labor. Therefore, for each dollar paid for direct labor in the section there is $1.50 expense; and under the plan of including indirect expense in the cost it is assumed that this expense is distributed uniformly, that each dollar of direct labor carries along the same amount of expense as every other dollar; so, after the direct labor on a piece of apparatus is determined in the manner already explained, this amount is multiplied by 1.5 to determine the indirect cost of the apparatus; this indirect cost being added to the direct material and direct labor and the total considered the actual factory cost.

ADMINISTRATION AND SELLING EXPENSE

After ascertaining the factory cost of an article it is necessary to know the total or commercial cost before the selling price can be intelligently set, and this is determined by practically the same method that is followed in arriving at the indirect expense. The total cost of administration and of selling in a given period, including the advertising necessary, is compared with the total factory cost of the apparatus sold during the same time, and the relation of the total administration and selling expense to the total factory cost is taken as the percentage to be added to the factory cost of each article to get the total or commercial cost, just as a percentage of the direct labor is added to the prime cost to ascertain the factory cost. This is something on the "blanket" method of arriving at the cost of output, but it is sufficiently reliable to answer the purpose, considering the expense that would be involved in getting it any other way.

Until recently the method has been considered generally satisfactory. A more up-to-date method of absorbing these expenses is to allocate to divisions of the sales department organization all expenses which can be identified as belonging to individual divisions (or in the case of smaller concerns, where no sub-division of the sales organization is made, to classes of apparatus) and pro-rating the remaining portion of the total of these expenses over all divisions, thereby securing differential rates of commercial overhead percentages to apply to the various lines of product handled by the different sales divisions.

PROFIT

After the total cost of an article is known, the next thing, of course, is to set the selling price. If a concern is manufacturing an article on which it has a patent, it need consider only the demand for the apparatus. But when a number of concerns are manufacturing practically the same line of apparatus and the consumer can meet his requirements more or less satisfactorily by the use of almost any one of perhaps a dozen different makes, competition not only makes it imperative that the cost of making and selling an article be accurately known, but in deciding upon the percentage of profit to be added, the consumer's ability to buy elsewhere must receive careful consideration.

GENERAL

Up to this point the subject has been limited to cost figuring which, as explained in the beginning, is only one of the many features embraced in the general subject of cost keeping; but this is such an important part of the scheme—the value of the whole system depending to such a great extent upon the accuracy of the actual cost figures—that when mentioned at all it requires and deserves considerable attention. There are a number of other interesting phases of the subject; such as departmentalization of the plant, individual superintendents being in charge of and responsible for the proper management of the different departments; each superintendent being charged with the amount invested in his department and credited with the cost of his output, this amount being watched by the management and the superintendent called upon for an explanation at the end of any month when the amount shown charged against him does not seem justified by the work on hand; how this amount invested in each department is measured upon the basis of $1.00 of net output, and how this measuring ratio is arrived at and its upward or downward tendency over a predetermined period carefully watched by the management and explanations demanded. It also would have been of interest to describe how the total investment in materials, labor and expense is controlled. Different concerns split the total up in various ways; in one case it is divided into three parts: raw material and supplies, finished parts and machines, and work in progress. This segregation is made to facilitate comparison from month to month; and each of these main divisions is again sub-divided into numerous items so that an abnormal condition at the end of any one month will not only be immediately seen but the point where the increase occurred can be located at once, thus making it possible to get at the actual cause without tedious investigation.

Another important part of cost keeping is the manner in which the different expenses going to make up the total indirect expense, are controlled. This total is divided into main divisions and these main divisions divided and sub-divided down to the point where it is possible to pick out the individual who is responsible for the total of, say janitor service, being high in a particular month.

The scope of this article does not permit of further treatment of methods of applying the results of costs analysis, the intent being for the most part to investigate the elements of cost itself; but the importance of such analysis cannot be too strongly urged for the modern progressive manufacturer, as a thorough knowledge of cost is essential to the certainty of successful production.

SHOP TESTING OF ELECTRICAL APPARATUS—VI

DIRECT-CURRENT GENERATORS—ADDITIONAL AND SPECIAL TESTS

Three-Wire Direct-Current Generators

THE three-wire generator has the same general structure as the ordinary two-wire generator, the differences being the addition of four collector rings connected to the armature winding at points 90 electrical degrees apart, as on a two-phase interconnected armature, and the division of the series field and commutating field into two halves, one-half being connected on each side of the line. The collector rings are connected to two coils of low resistance but high inductance, called "balance coils," the connections being made in such a way that the two ends of each coil are 180 electrical degrees apart. The middle points of the two balance coils are joined, and connected to the "neutral wire" of the three-wire system.*

The following electrical tests are made on machines of this type in addition to those on the standard direct-current generator:

1—Resistances of both halves of the series and commutating fields.
2—Ratio of voltages between the different rings.
3—Unbalanced regulation.

RATIO OF ALTERNATING-CURRENT VOLTAGES

Readings of voltage between rings are taken in all cases. These correspond to the values inherent in the standard two-phase, interconnected winding, the voltage between rings *1* and *3* and *2* and *4* being 71 percent of the direct-current voltage; that between adjacent rings, and between the two outside rings, 50 percent, ring *1* being nearest to the armature winding. Corresponding readings must be alike, otherwise there is probably some error in the location of the taps to the armature winding.

REGULATION

Since the series field is split in halves, it is necessary to adjust similar German silver shunts to each half, when taking the standard regulation. With this exception the test is made as previously outlined.

Unbalanced Regulation—In addition to the standard regulation, the variation in voltage under conditions of unbalanced load is determined when so desired. The percent unbalance is limited by the capacity of the balance coils used, these being usually built to take care of 25 percent unbalance, i. e., 25 percent of the normal current flowing through the neutral wire. The variation in voltage due to excess load on the one side is independent of the balanced portion of the load on each side. This being the case, the test to check the variation may be made at any convenient values; it is usually most convenient, however, to have no load on one side of the line, and the excess amount on the other.

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*See article on "Three-Wire Generators," in the JOURNAL for May, 1906, p. 290.

The connections should be made as in Fig. 1. If two voltmeters are not available for reading the voltage between the neutral and both outside wires, a double-throw switch may be used and both readings taken with the same instrument. The machine is started up and the brushes set in the same position as used on the standard regulation test. With normal voltage across the outside leads, a load of approximately one-fourth the full unbalanced load is applied between the neutral and outside leads, and readings of terminal volts and amperes, shunt amperes and voltage from neutral to each outside wire are taken. The load is then increased by suitable increments up to one and one-fourth load on the balance coils, complete readings being taken on each point. At normal load on the balance coils the unbalanced load should be switched from one side of the line to the other; the drop in voltage should be the same in each case. Both voltage curves should be plotted with the line amperes load on the neutral wire as abscissæ and volts as ordinates.

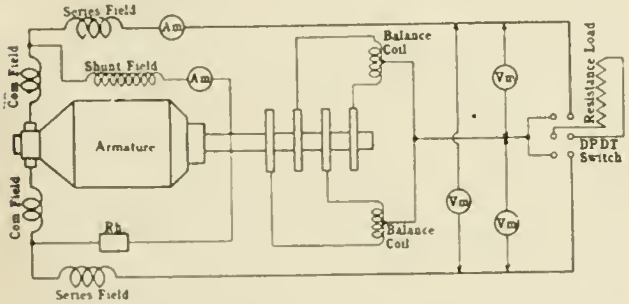

FIG. 1—CONNECTIONS FOR TESTING THREE-WIRE GENERATOR FOR UNBALANCED REGULATION

SERIES GENERATORS

Voltage Regulation—The terminal voltage of a series generator varies with the load, and the adjustment of the shunt on the series field should be made so as to give the rated voltage at the rated load and speed as called for on the name plate. Before starting the test, all wiring should be carefully examined, to see that the machine and all instruments are propery connected, and that the circuit-breaker is in good working order. A small load is first placed on the machine to see if it will pick up; if trouble be experienced in this respect, the brushes should be momentarily short-circuited, which process is known as "flashing the field." If the machine still refuses to pick up, it will be necessary to excite the fields separately. The machine should be run long enough to reach normal operating temperature before adjusting the shunt on the series field, if one is required.

This test should be made in the same manner as a saturation curve, starting with a low current and gradually increasing it until 50 percent overload is reached. Complete readings of terminal volts, amperes and speed should be taken at each point, and the commutation noted. The full-load current and drop in the series and commutating field shunts, if any are required, should also be measured. The curve should be plotted with line amperes as abscissae and volts as ordinates.

Other tests on this type of generator are run the same as on shunt or compound wound machines.

Special Tests for Direct-Current Generators

In addition to the tests previously described, which comprise the tests ordinarily made on a factory test floor, or by a central station, there are a variety of special tests which are usually made only on new lines of apparatus or where special investigations of performance are required to secure engineering data, or in special laboratories. Since they are special tests, the method of operation depends on the type of data desired, and only a few of the more common ones will be described.

FIELD FORM

This test is taken to determine the correctness of the design of the field poles, and the proper location of the brushes with reference to the commutating position. It is usually made at no load, full load, and at such other loads as may be desired. The most accurate method of making this test is with the oscillograph, but on account of the special connections required, the following method is often used:

A template is made from a narrow strip of fibre about one-sixteenth inch thick and long enough to reach a little on either side of two adjacent brush arms of similar polarity; this strip should be perforated with a line of small holes spaced the distance of one commutator bar apart, so that the voltage from bar to bar may be measured. These holes should be just large enough to admit the point of a hard lead pencil. A pair of voltmeter points are made from two such pencils, and connected to a low-reading voltmeter. The fibre template is placed on the commutator and fastened in position. It is usually best to cut out the fibre to fit around the brushes, as this gives it better support. The brushes are set on the full-load neutral, and terminal volts, amperes and speed held constant; then, beginning at one end, successive readings of the voltage between each pair of holes across the template are taken, the points being always moved in the direction of rotation. If possible, all the readings should be taken on the same scale. The commutator should be quite smooth where the pencil points touch, to secure the best results. These readings should be noted, with the number of perforations between which each is taken; this will give the exact location of the brushes with respect to the holes in the template. The curve is plotted with position of points as abscissæ and volts as ordinates, noting also the location of the brushes, as in Fig. 2.

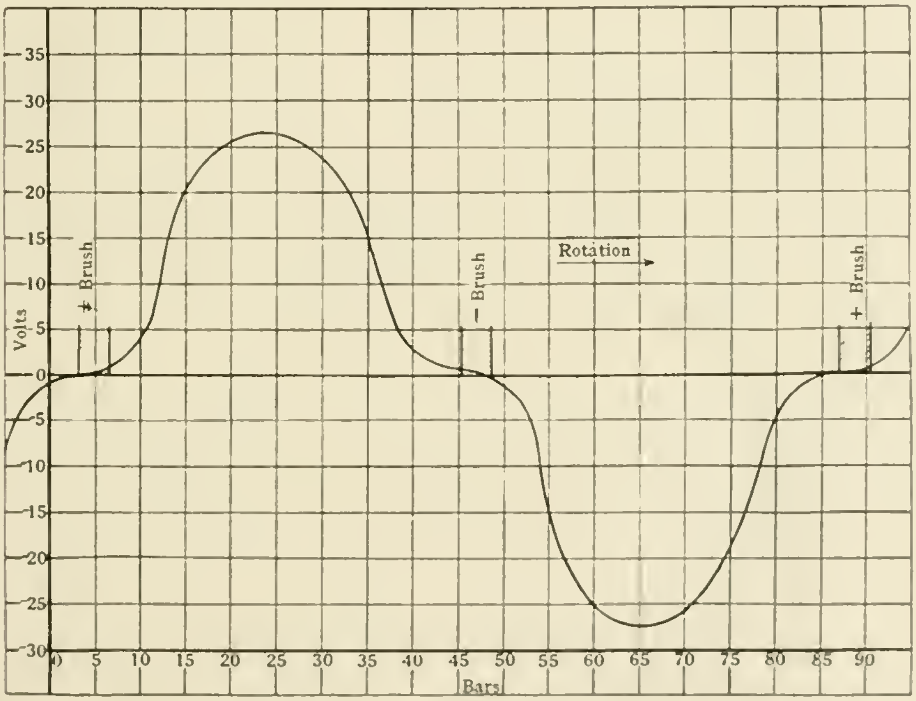

FIG. 2—TYPICAL NO LOAD FIELD FORM CURVE OF DIRECT CURRENT GENERATOR

SATURATION OF THE COMMUTATING-POLE

The saturation of the commutating poles is obtained by running the machine under load with the commutating poles either separately excited, or connected in series with the armature of a booster, or by connecting a separate circuit in parallel. The strength of the commutating fields can easily be controlled by any of these methods. Fig. 3 shows the connections for the first method, and Fig. 4 for the second.

All connections should be checked with the corresponding diagram, and suitable meters connected in their proper circuits, noting carefully that the meter intended to read the current in the commutating winding will read the total current in that circuit and not a part only. The machine is started in the same manner as for load test and loaded to approximately one-half load. The excitation of the commutating poles is then increased until the machine just begins to spark and a complete reading of terminal volts and amperes, shunt field amperes, commutating field amperes, speed and brush drop* are taken. A second reading at the same load is taken with commutating excitation decreased as much as possible, while still retaining good commutation. These readings are taken also at normal load, 150 percent and 200 percent load.

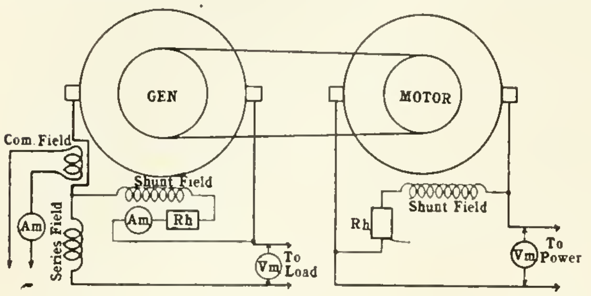

FIG. 3—CONNECTIONS FOR RUNNING SATURATION TEST ON COMMUTATING FIELD, WITH SEPARATE EXCITATION

Plotting these excitations as ordinates against line amperes as abscissæ, Fig. 5, gives two saturation curves, the space between them being the region of good commutation. With any given excitation then, it is evident that the commutation characteristic of the machine at any load can easily be determined. The brush curves taken are evidence of the amount of over or under-compensation, as well as the actual voltage being commutated. The data in Table I gives the results taken on the 2000 kilowatt generator under consideration and the form in which it should be recorded, except that the meter data has been omitted.

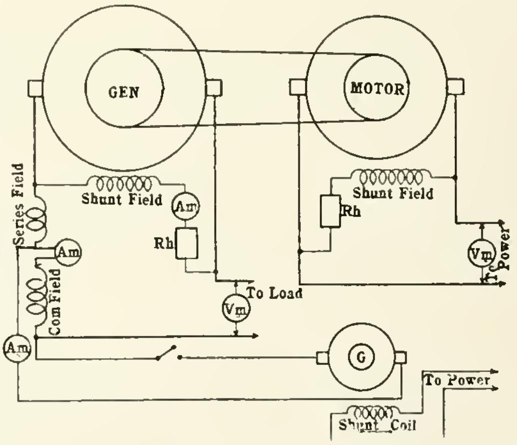

FIG. 4—CONNECTIONS FOR RUNNING SATURATION TEST ON COMMUTATING FIELD WITH FIELD CIRCUIT SHUNTED BY A BOOSTER CIRCUIT

FLICKER TEST

This is commonly made on machines of a new design. It consists in throwing the load off and on and noting its effect on a sensitive lamp connected across the terminals of the machine. The lamp or lamps used in this test should be so arranged that the filament is not directly visible, but the light as reflected on some white surface may be readily observed and its variation noted.

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*See the JOURNAL for April, 1913, p. 376.

Commercial Tests

In the case of machines of standard design, only such routine tests are made regularly as are necessary to determine if mechanical defects exist and to prove the similarity of the machine under test to the standard machine of the same design.

Operations Common to All Generators — The commutator should be seasoned, if necessary, and all the brushes ground in carefully and set in approximately the no-load neutral position. The number, size, make and grade of the carbons should be noted when starting the temperature or observation run. The machine should be belted to a motor of sufficient capacity to carry, momentarily, approximately double load on the generator, and a careful mechanical inspection made.

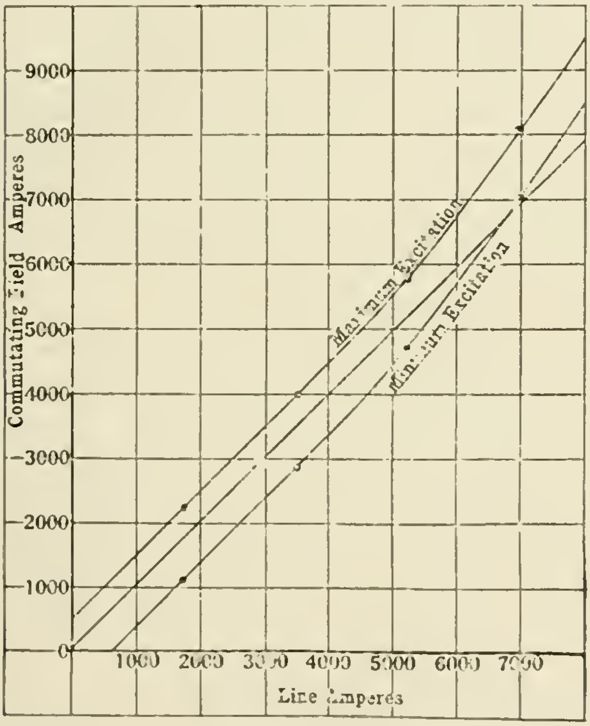

FIG. 5—COMMUTATING POLE SATURATION CURVES

The location of the neutral should be determined as previously directed, and with brushes set in that position, a corresponding mark made on the rocker arm and frame. In the case of commutating-pole machines the rocker arm should be dowelled in this position. In other machines an identification mark should be made with a chisel or other means, so as to be located readily at any time. On machines with commutating poles the compensation should next be checked by taking the voltage drop under the brushes, and a shunt adjusted to the commutating field if found necessary.

Load tests vary according to the type of machine. No machine, however, should be approved on which the commutation is not sparkless at the end of the normal load test. The commutator must show a tendency to polish and not to blacken or burn. The condition of the commutator should be noted on the record sheet both before and after each test.

After all other tests have been completed, an insulation or ground test is made. The voltage used is generally 1 500 volts on machines rated at 400 volts or under, and 2 000 volts on 500 and 750-volt machines.*

Belted Generators Up to 50 Kilowatts—On machines of this class having commutating poles, the neutral is checked by taking three-point regulation in both directions of rotation. This also comprises the commercial test; the no-load reading giving a point on the saturation curve to compare with the test on the standard machine. Commutation and general operation should be noted at each point and readings taken of line amperes and volts, field current, field volts, and speed. At normal load, readings of current shunted from series or commutating windings, if any, and the drop across each, should also be noted. As these machines have their own bearings, they should be run as motors for a few minutes, so that the end play may be properly adjusted and the mechanical inspection made.

TABLE I—COMMUTATING-POLE SATURATION

Generator Data			Brush Drops							
			+ Brush				— Brush			
Per Cent Load	Line Amps.	Aux. Amps.	1	2	3	4	1	2	3	4
50	1750	1750	1.0	.7	6	4	.9	.66	.33	—.1
	1750	1100	26	3	66	.8	.3	.35	.69	.91
	1750	2240	.80	6	—.1	—1.66	1.1	.8	.10	—.66
100	3480	3480	.7	.77	.67	.4	.9	.87	.87	.7
	3480	2870	.5	7	1.33	1.5	57	.63	.90	1.1
	3480	3980	.57	4	.0	—.1	.8	.7	0	—1.66
150	5200	5200	.66	.9	.66	.37	.9	.5	.47	.4
	5200	4730	.8	1.06	1.33	1.66	.66	.7	1.1	1.66
	5200	5770	.67	.6	.27	—.09	.73	.9	.2	—.1
200	7000	7000	.47	1.08	1.2	1.7	.5	1.1	1.31	1.75
	7000	7100	57	.61	.68	72	.6	63	.69	.73
	7000	8100	72	64	53	31	.73	65	54	.32

Engine-type and Large Belted Commutating-Pole Generators—In addition to those specified above, the following tests are also made on these machines. As a check on the no-load saturation, three points, 75, 100, and 125 percent voltage, are taken. In some cases, load saturation is taken in addition to the standard regulation test, so that the current in the series field for any regulation may be computed. An observation test is run at 125 percent load for two hours. During this test the general operation of the machine is observed carefully, the commutation in particular being noted.

Non-commutating Pole Generators—On non-commutating pole generators of all types the commercial test is the same as that for commutating-pole generators given above, except that the brushes are shifted to the running position.

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*See section on "Insulation Testing" in the JOURNAL for March, 1913.

Methods of Loading Direct-Current Generators

There are two general methods by which a direct-current machine may be loaded:

1—By driving the machine as a generator, either electrically or mechanically, and loading it on a resistance or water rheostat.

2—By "loading back" on one or more similar machines.

Resistance Method—In this method the generator is belted or coupled to a direct-current motor or other source of power capable of driving the generator at 50 percent overload continuously and 100 percent overload momentarily. The shunt field of the driving motor is adjusted to give the generator its rated speed; the generator field circuit is closed, and the voltage brought up to normal, after which the line switch is closed to connect it to a resistor of suitable capacity, and its resistance adjusted to give the desired load.

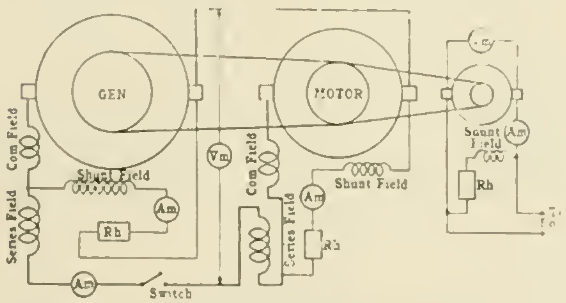

FIG. 6—LOADING BACK BY MECHANICAL LOSS SUPPLY METHOD

This method is expensive and wasteful, since all the power is absorbed in the resistor, and therefore it is used only when other means are not available. Waste of power can be avoided by the "loading back" method, which is commonly used, especially in the case of large machines and motor-generator sets. The principle of this method is to run two or more machines on test under load, one machine acting as load for the other, only the power necessary to make up the electrical and mechanical losses being supplied from another source. This may be done in three different ways.:

Mechanical Loss Supply Method—In this method two machines of the same size and voltage are coupled or belted together and driven by a third machine large enough to supply the losses of both. The machines are connected as in Fig. 6. If the machines have series fields, they should be connected so as to boost one another. The series field of the generator which is to run as a motor must be reversed before starting the test; otherwise it will work against the shunt field instead of strengthening it. The driving motor must be large enough to supply all the losses of the set up to 100 percent overload. The field of the driving motor should have a rheostat in series with it in order to control the speed of the set.

In starting up, the switch between the motor and generator should be left open. The field circuit of the generator is closed, and the machine brought up to normal voltage; then the same is done for the motor, except that it should be brought up to a voltage slightly below that of the generator; these voltages should be checked several times before closing the switch. On closing the switch the load ammeter should show a small deflection, since the motor has the lower voltage. If the ammeter reads in the wrong direction, the leads should be reversed. When the line switch is closed, the load must be watched closely, for if the machines are not similar or adjusted similarly, the load is likely to increase very rapidly. If it is impossible to control the load by the shunt field of the motor, it will be necessary to adjust a shunt on the series field of either or both machines until their characteristics are such that when the line switch is closed, the load can easily be controlled. After the operation is satisfactory, the regulation and temperature runs should be taken.

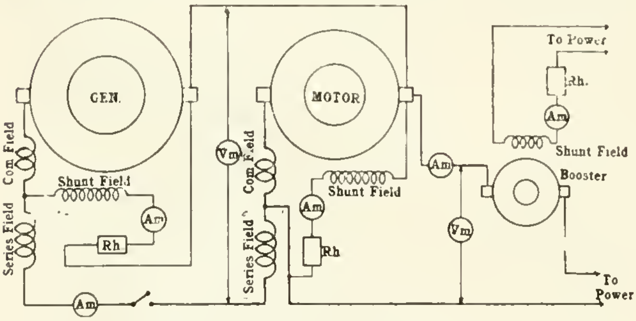

FIG. 7—LOADING BACK BY ELECTRICAL LOSS SUPPLY METHOD

The brushes must be set so that they are approximately in their running position before paralleling the machines, and the load should be watched carefully when shifting the brushes after paralleling, for any change in brush position will change the load. Under no circumstances should the field circuit of either machine be opened while the line switch is closed, as this will cause the machines to take an excessive load, which would probably damage them seriously. If the generator is the one being tested, its shunt field resistance should be held constant and the load controlled by the shunt field of the motor.

Electrical Loss Supply—This method consists in connecting two similar machines, either directly or by belt, and supplying the losses directly from the line to the machine running as a motor. It gives very satisfactory results when two similar machines are used, but if the motor and generator are of different types, the load is likely to be rather unsteady and will need constant attention. The same precautions as to the load noted in the preceding method must be taken in this case. Especial care should be taken that the circuit breaker is in good working order, and it should be tripped two or three times as a test. Connections are as in Fig. 7. The machine which is to run as a motor should be started from the line, and the rheostats in the shunt field adjusted to obtain normal speed, keeping the line voltage several volts below the required generator voltage. The field on the generator is then closed, and its shunt field adjusted to normal voltage. The motor voltage and voltage of the generator should be checked several times as before, to see that they are set correctly, after which the line switch may be closed. The load ammeter must be watched closely to see that it does not read in the wrong direction. If the generator takes its load too quickly, the circuit breaker should be tripped before damage is done to either machine; then the necessary shunts should be adjusted on the series fields, and the machines paralleled again. After obtaining satisfactory operation, the required tests may be made.

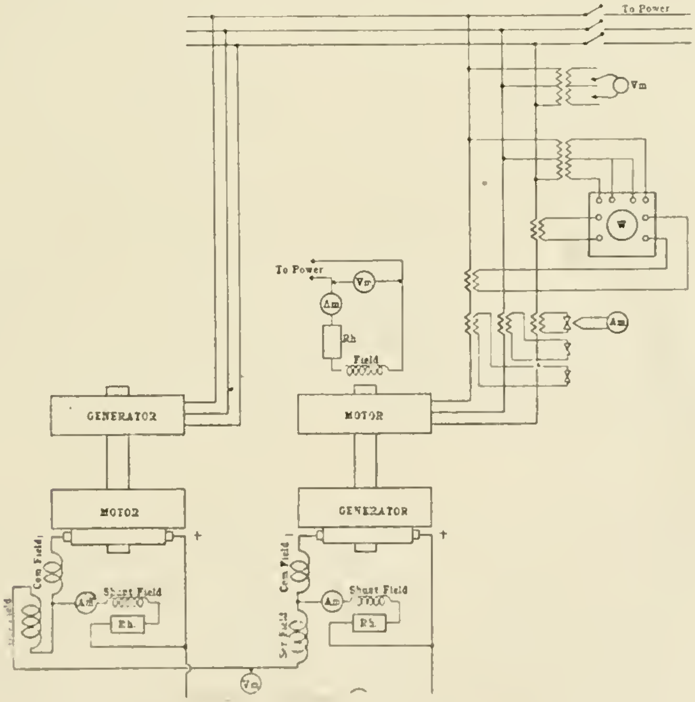

FIG. 8—LOADING BACK A MOTOR-GENERATOR SET BY THE ELECTRICAL LOSS SUPPLY METHOD

If this method is used with compound wound generators, the voltage on the loss supply circuit will have to be increased as the load increases to take care of the increased voltage due to the compounding effect of the generator. The voltage of the loss supply circuit should be set for the no-load voltage of the generator under test; then, after the machines are paralleled, the shunt field of the motor is reduced to obtain the desired load, while the line voltage of the loss supply circuit is increased until the desired speed is obtained.

Motor Generator Sets—In this method both machines are direct connected to either direct or alternating-current motors. The machines should be connected up as in Fig. 8. When the sets have induction motors, it is necessary to have a part or all of the losses supplied on the alternating-current side. If means for starting the motors are not available, the sets may be started from the direct-current side, in which case it will be necessary to phase out the induction motors before paralleling the sets. After starting one set, any one of the leads from the induction motor of that set, which, of course, will be running as a generator, should be connected to a terminal of the line, and the voltage between the remaining phases measured. If it is greater than normal the connections should be changed. The line switch may now be closed, at the same time opening the circuit-breaker on the direct-current side. The second set should then be started in the same way, after which the two sets can be paralleled on the direct-current side. When the generators are direct-connected to synchronous motors, the losses can be supplied either to the direct-current or the alternating-current machine or both.

When the generators are direct-connected to synchronous motors, in starting from the direct-current end, the synchronous machines must be both phased out and synchronized before paralleling the sets. If it is possible to start from the alternating end, with either synchronous or induction motors, both machines may be started at once and the process is greatly simplified. The brushes of the direct-current machines must be set so that they are approximately in their running position before paralleling the machines, and the load should be watched carefully when shifting brushes after paralleling.

After having both outfits running, the direct-current machines may be paralleled as described above; then the shunt field current of the direct-current machine running as a motor should be reduced. This will cause it to take the load, driving the alternating-current machine as a generator loading back into the line.

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911—Operation of Rotary Converter—Would a rotary converter connected in on both direct and alternating-current sides run away if the shunt field should happen to break down? F. J. B. (N. Y.

No. A rotary converter can only run away under the following conditions:—Disconnection or loss of voltage on the alternating-current side and operating in parallel with an independent source of direct current, so that the direct current will be maintained when the alternating-current circuit supplying the rotary converter fails and, further, when the excitation conditions are such that a weak field results. F. D. N.

912—Selection of Hoisting Motors—Is it good practice to use wound secondary induction motors on single drum mine hoisting engines? In the small shafts and new developments near here they use wound secondary induction motors with external resistance which is cut out step by step on starting. Would not direct-current series motors be better for this work? The motors now used are 100 hp, three-phase, 60 cycles, 220 volts and the depth of shafts is from 300 to 600 feet, a level for each 100 feet, stops frequent. The maintenance cost of direct-current motors would probably be considerably higher, but it seems to me that the time saved by the higher starting torque of the direct-current motor would more than offset any difference in cost maintenance and that a direct-current motor would operate with less peaks, less copper in feeders and less line loss. The hoists are double-geared, and from what I can learn the first one was installed before the commutating pole direct-current motor had made its reputation.

G. S. W. (ARIZ.)

The increasing use of central station power by the coal and metal mines is responsible for the increasing use of the wound rotor induction motor for small and medium sized hoists. No difficulty is experienced in obtaining ample starting torque from an induction motor designed for hoist service, and this motor has the added advantage of being able to utilize any voltage, two or three phase, up to and including 2200 volts. The induction motor can be used to return energy to the line when lowering a loaded or empty cage. A direct-current motor requires a supply of direct-current power which in most cases must be obtained from rotary converters or motor-generator sets. For hoist service the direct-current motor is generally series or compound. The peak loads will be essentially the same with either direct or alternating-current motor. The efficiency is practically the same with either system since one-half of the accelerating power is lost in the rheostat. For hoists of medium and large size, liquid rheostats can be used for the alternating-current motor, which offer a much simpler control than can be obtained for a direct-current motor. G. B.

913—Operation of Exciters in Parallel—The general method of supplying field current to alternators working in parallel appears to consist in connecting the fields to two-pole, double-throw switches which enables the station attendant to connect each of the fields to the corresponding exciter on an extension of the armature shaft, or to a separate source, for instance a battery. Some large central stations have adopted a different system, viz., to run all the exciters in parallel and branch the fields from the exciter bus bars. It is believed that by so doing there is less chance of a machine falling out of step than when the exciters are electrically independent. Please give relative merits of these methods. P. B. (HOLLAND)

General practice in the United States for excitation of alternating-current generators is to operate all exciters in parallel when there is more than one exciter. The field currents for the alternators are then taken from a common set of bus-bars. It is further customary, when a considerable number of alternators are used, to employ an exciter of sufficient capacity to excite several of the alternators. The practice of having a separate exciter for each alternator is not usually employed. No particular difficulty has developed with this method of operation and it has a considerable number of points of advantage over the first method mentioned. P. M. L.

914—Reducing Speed of Shunt Motor—I have a three hp, direct-current shunt motor, 550 volts, 1 950 r.p.m., two poles. The field is wound with No. 25 wire and has 4 640 ampere-turns. The armature has 36 coils, 20 turns to a coil. Will you please advise how to reduce the speed to about 1 250 r.p.m. I rewound the coil with No. 23 wire, giving about 9 000 ampere-turns, but this only reduced the speed about 200 revolutions.

R. L. M. (PENNA.)

Ordinarily it is not possible to effect as great a change in speed as you desire by strengthening the field of the motor as, if the magnetic circuit is at all saturated, increasing the number of ampere-turns does not produce anything like a proportionate increase in field strength. Probably the only thing to do would be to rewind the armature, increasing the number of turns approximately in proportion to the desired speed reduction. As smaller wire will have to be used, the IR drop will be increased perhaps 30 percent. Assuming that the IR drop is now 100 volts and is increased to 130, then the number of turns per coil would be approximately $20 \times \frac{1750}{1250} \times \frac{420}{450} = 26$.

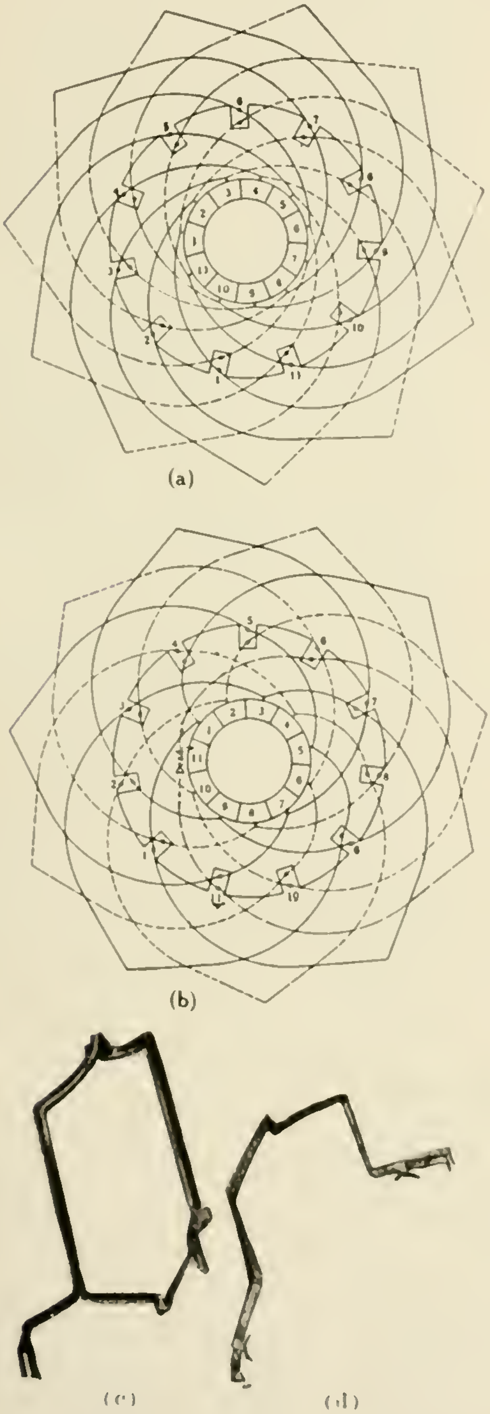
J. M. H.

915—Connection of 220 Volt Direct-Current Motor for 110 Volts—A 220 volt, four-pole armature with series or two circuit winding, having three coils per slot, 37 slots, 111 commutator bars as indicated schematically, and with fewer bars and turns in Fig. 915 (a), is to be re-connected for 110 volts, if possible, without rewinding. Could a double series winding be used, cutting out one coil and one commutator bar, making a 110 coil machine, as shown (simplified) in Fig. 915 (b). Upon testing such an armature with dry cells, buzzer and telephone receiver I found that it was possible when testing, to hold the terminals of the test circuit on the bars of one winding and the other terminal on the second winding and still get no evidence of a continuous circuit between the two windings. This happens only when both windings are all connected up. Please explain this.

F.B.

It is possible to re-connect the armature as suggested but it will be much better to inter-connect the two windings by inter-connecting every two commutator bars. In effect this will give a 55 bar armature with each bar of twice the present width. It will also be necessary to use wider brushes, as the current will be doubled at 110 volts for the same output. If there are an even number of turns per coil (say two turns), it would be much better to open the coils and spread them as shown in Figs. 915 (c) and (d), so as to connect them in parallel. It will be evident that this can be done without cutting out a coil, but will require a wider brush as before. It is very questionable if the coil ends would be of sufficient length to carry out this idea, but if it is possible to do it the operation of the machine as re-wound will be much better than with the makeshift arrangement proposed. In regard to the testing results obtained with telephone receiver and buzzer, it is probable that the two parallel coils of the armature circuit were in each case connected to separate commutator bars, the same as in arrangement suggested above. In this case it will be seen that, while the two circuits operate in parallel when the machine is running, they are in reality insulated from one another throughout.

C.O.S.



FIGS. 915 (a), (b), (c) AND (d)

916—Switchboard Connections—(a) What kind of a receptacle is shown on p. 165 of the February issue and how are the plug and receptacle wired? (b) On the ground receptacle in lower right hand corner there are the letters *G. T. L.* What do they mean and, if this is a receptacle, how is the plug wired? (c) In the upper right hand corner of panel *I* there are two potential transformers. Why are they connected up different from the other two on panel *II*?

C. J. B. (ILL.)

(a) This is a three-point plug receptacle wired as shown in Fig. 916 (a). The plug connects either *L* and *T*, or *T* and *G*, depending on the distance the plug is pushed in. (b) *G. T. L.* means ground, transformer, line. (c) One of each pair is connected to the same phase of the two generators for synchronizing and voltage readings. The other two connect to the bus-bars for synchronizing voltage and potential coils of wattmeters.

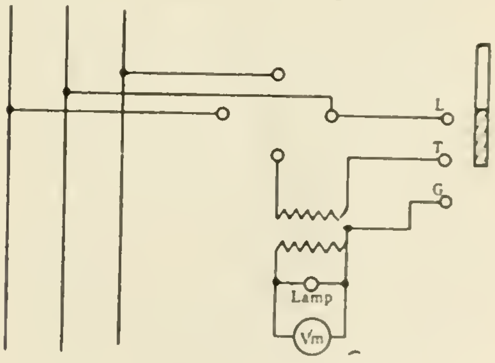


FIG. 916 (a)

917—Bell Load for Telephone Generator—With reference to question No. 885, would the character of the load have anything to do with such a case?

M. H. V. (PENNA.)

It would. The telephone bells furnish an inductive load which would cause the current to lag considerably, tending to demagnetize the fields. Therefore when the alternating current load comes on, the field is weakened or demagnetized considerably, which in turn lowers the direct current voltage. Lowering the direct-current voltage, together with the field demagnetization due to the alternating current load, weakens the field still more. This action is cumulative so that the voltage may fall off entirely, especially if the machine operates fairly low on the saturation curve, where it is sensitive to small changes in field excitation. The most practicable method of curing the trouble is to excite the generator separately, say from the storage battery. How much the speed drops when the load comes on, depends on the characteristics of the driving motor. C. G. L.

918—**Operation of Compound-Wound Motor on Variable Voltage**—Why does a compound-wound motor maintain more constant speed than a shunt motor on variable voltage when driving a centrifugal pump, as stated in the March JOURNAL, p. 235? Ordinarily it does not, but I believe the clue here is in the load-speed curve of the pump. C. W. D. (PENNA.)

The questioner is correct in that the tendency of the motor to maintain constant speed with varying voltage is due to the load speed characteristics of shunt and compound motors. The compound motor for any impressed voltage has a drooping speed characteristic, the drooping character of the speed curve being accentuated with decreasing impressed volts, whereas the speed load curve of a shunt motor is more nearly flat and varies less in slope with the impressed voltage. With either motor, as the line voltage becomes lower, the speed becomes less. However, the power necessary to drive a centrifugal pump decreases much more rapidly than does the speed. Thus the torque of the motor and hence the current input is materially lessened. This in a compound motor weakens the series field and hence the field flux, with the result that the motor speed does not decrease as greatly as in the case of the shunt motor. The net result of this combined action is to cause a smaller variation in speed with fluctuating voltage with a compound motor than with a shunt motor. This statement applies in more marked degree to that type of load in which the power required drops off more rapidly than the speed. E. C. W. & A. C. L.

919—**"Frequency of Alternator"**—In answering question 865 as to whether ten poles can be removed from a twelve-pole alternator without affecting the frequency, the speed remaining the same, it is stated that the frequency remains the same. Now the frequency of an alternator depends on the formula, $n = (p \div 2) \times s$, when $n =$ the frequency, $p =$ the number of poles, $s =$ the speed in revolutions per second. If the alternator has a speed of 600 r.p.m. the frequency is 60 cycles and 12 poles, removing 10 poles, leaves 2. Applying the formula, $s = 600 \div 60 = 10$ revolutions per second. Thus $n = (2 \div 2) \times 10 = 10$ cycles per second. The frequency would therefore be reduced to 10 cycles, the speed remaining the same. Am I right? M. J. K. (WIS.)

Possibly our previous answer was too brief. The formula as stated above is correct, when applied in the way intended. However, the polarity of an alternating-current generator extends to the armature winding as well as the fields, and removing ten of twelve poles, and leaving the remaining two in their original position, does not of course affect in any way the armature winding nor its polarity. It simply means that ten-twelfths of the total winding is not having any voltage generated in it at any given instant. The e.m.f. generated in the remaining two-twelfths of the winding is at its normal frequency, since the speed of the poles relative to the winding is exactly normal. This means that in any given coil in a 60-cycle generator, a 60-cycle e.m.f. is generated every sixth complete cycle, and the coil is dead during the intervening five cycles. Since all the coils in the generator are usually connected in series, there is no time at which all the coils are dead, and hence a normal 60-cycle e.m.f. is generated at one-sixth the normal voltage. C. R. R.

920—**Pressing Rotor on Shaft**—Usually when large alternators are received at the point of installation, the rotor has been removed from the shaft by means of a hydraulic press, especially designed for the purpose. When installing, how are we to get the rotor on the shaft again? Are screw jacks used or is there a special temporary device for the purpose which is easily applicable. J. G. K. (CANADA)

The usual method is to use a hydraulic press to force the shaft into the hub of the rotor. If the shaft is not above about 10 inches in diameter and press is not available, the shaft can usually be forced into place by using bolts fastened through the hub of the rotor and to a cross-bar over the end of the shaft. This method has been used successfully on several ten and one-half inch shafts. The precaution should be observed to keep the shaft in motion after it is once started until it reaches its final position. W. G. M.

921—**Booster Transformers**—We are operating three 40 k.v.a. single-phase, 60 cycle, 2 200/220 volts transformers as boosters on one of our 4 000-volt feeder circuits connected as shown in Fig. 921 (a). As the voltage is high at the time of light load it was proposed to cut out the booster transformers when not needed by means of an oil switch in the primary circuit as indicated in Fig. 921 (a). There was no difficulty with this arrangement at no-load but when the oil switch was opened with about 100 amperes flowing in the feeder, the oil switch broke down due to high voltage. Why could not the oil switch be opened without causing trouble and how can booster transformers be connected to the circuit so that they may be disconnected without cutting out service even for a short while. J. B. C. (ILL.)

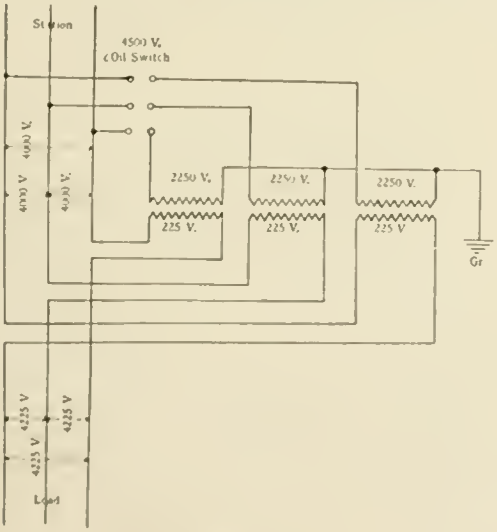


FIG. 921 (a)

Trouble is to be expected when opening the switch with load on the line. Since the boosting transformer has its low tension winding connected in series with the line, the current flowing through this winding will cause the voltage on the high tension winding to rise to a value much above normal the instant the switch is opened. This action is exactly similar to what occurs with a current transformer when the secondary is opened. The current through one winding causes magnetic saturation in the iron and an abnormally high voltage is set up in the other winding. There does not seem to be any satisfactory way of opening this switch, except by first cutting the line out of service, short-circuiting the transformer secondary, opening the transformer primary and then putting the line back into service again. W. M. M.

922—**Connections for Transformation from Three-Phase, Four-Wire System to Two-Phase**—We have a three-phase, four-wire circuit with grounded neutral, 2 300 volts between phase wires and neutral. We have available 1 100-2 200/110-220 volt transformers with taps for Scott connection. Please tell how to connect the transformers for operating a 220-volt, two-phase, four-wire motor circuit. E. M. B. (TEXAS)

This result can be accomplished by the use of three transformers connected as shown in Fig. 922 (a).

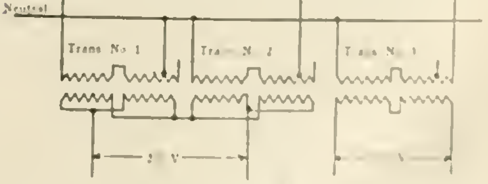


FIG. 922 (a)

Transformers *1* and *2* are connected to the three-phase circuit using the 87 percent taps of the high tension windings while the two halves of the low tension winding of each transformer are connected in parallel and the two transformers connected in series. Transformer *3* has its whole high tension winding connected across the three-phase circuit and the two halves of the low tension winding are connected in series. Transformers *1* and *2* need only have 58 percent of the capacity of transformer *3*.

W. M. M.

923—Commutating Pole Winding—Can you tell me approximately the number of turns of wire on the commutating pole of a generator in percent as compared with the regular pole windings? Please give sketch of the connections and show direction of coils on each pole for a bi-polar compound commutating field generator.

G. W. M. (OREGON)

No direct relation exists between the ampere-turns of the commutating pole winding and the main winding. The turns of the commutating pole winding should be such that its magnetomotive force will exceed the armature magneto-motive force by an amount which will maintain under the commutating pole sufficient flux for reversal of current in the coils short-circuited by the brushes. This flux should have such a value and be so distributed that the short-circuited coils cutting it, will have generated at each instant an e.m.f. equal and opposed to the e.m.f. induced in each by self and mutual induction through current reversal.

A. C. L.

924—Booster Transformer—We are transmitting 25 kilowatts at 2 300 volts for incandenscent lights, which reaches the center of distribution at rather low voltage. Would it be practicable to boost this voltage ten percent by using an ordinary 25 kilowatt lighting transformer (230-2 300) by connecting the primary across the line in multiple and connecting the secondary in series with the 2 300 volt circuit, beyond where the primary of the transformer is connected?

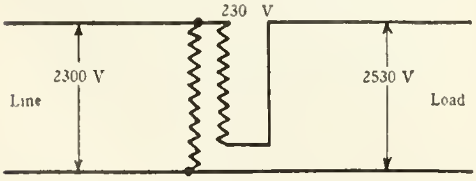


FIG. 924 (a)

F. E. B. (S. CAROLINA)

This is correct in principle. The only trouble is that it puts a 2 530-volt stress on a winding intended for operation at only 230 volts. However, there is a fair probability that a modern transformer might stand such service.

W. M. M.

925—Operation of Auto-Transformers—(a)—Given two 30 000 to 10 000 volt auto transformers in open delta, as in question No. 829, what would happen to the apparatus connected to the 10 000 volt circuit, transformers, lighting arresters, etc., if a ground should occur on one of the two open legs of the 30 000 volt circuit? (b)—What would be the effect on the auto transformer, particularly with reference to the voltage delivered at the 10 000 volt taps, without load, and also with reference to the 440 volt secondary, if the charging current in a line served from the 10 000 volt taps is less than the ampere capacity of the auto transformers, but considerably in excess of their normal charging current?

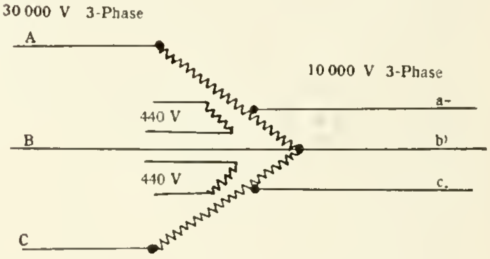


FIG. 925 (a)

J. C. D. (MONTANA)

(a)—Operating in this manner is liable to cause trouble unless the common wire, *Bb*, Fig. 925 (a) is grounded. If *Bb* is ungrounded and a ground should occur on *A*, we will have, *a* 20 000 volts above ground, *b* 30 000 volts above ground and *c* 26 500 volts above ground. It is evident that such a condition would be dangerous to the 10 000 volt circuit. If *Bb* is permanently grounded, no such dangerous condition can arise.

(b)—If you refer to the regulation of the transformers, the effect of the charging current of the line would be small. The charging current would of course act only as a capacity load on the transformers.

W. M. M.

NATIONAL ELECTRIC LIGHT ASSOCIATION CONVENTION

Program of General, Technical and Commercial, Accounting, Hydro-Electric and Public Sessions.

The annual convention of the National Electric Light Association will be held in Chicago, June 2-6, at the new El Medinah Temple. The program follows:

Monday, June 2—Registration and opening of exhibits. Reception in evening.

Tuesday, 10:00 A. M.—Main Auditorium, Room No. 1—Address of President Tait; Report of the Committee on Organization of the Industry—H. H. Scott, Doherty Operating Company; Report of Secretary, T. C. Martin; Report of Insurance Expert—W. H. Blood, Jr., Stone & Webster Corporation; Report of Committee on Progress—T. C. Martin, Secretary; Report on Question Box—S. A. Sewall, Asst. to Secretary; Paper: "Anticipation"—Paul Lupke, Trenton, N. J., Public Service Electric Company.

Tuedsay, 2:30 P. M.—Main Auditorium, Room No. 1.—First Technical Session—Report of Meter Committee (with Third Edition of Code for Electricity Meters)—W. H. Fellows, Washington, D. C., Potomac Electric Power Company; Report of Committee on Grounding Secondaries—W. H. Blood, Jr., Boston, Stone and Webster Corporation; Report of Lamp Committee—Frank W. Smith, New York, United Electric Light & Power Company; New Incandescent Lamp Development, J. E. Randall, Cleveland, National Electric Lamp Association; Paper: "The Incandescent Lamp and Its Relation to Lighting Service"—R. E. Campbell and W. C. Cooper, Cleveland National Electric Lamp Association; Report of Committee on Measurements and Values—Dr. A. E. Kennelly, Cambridge, Mass., Harvard University.

Tuesday, 2:30 P. M.—Lawn Tent, Room No. 2—First Commercial Session—Address of Chariman of the Section, Edward W. Lloyd, Chicago, Commonwealth Edison Company; Report of Finance Committee—T. I. Jones, Brooklyn, Edison Electric Illuminating Company; Report of Membership Committee—J. F. Becker, New York, United Electric Light & Power Company; Report of Publications Committee—Douglass Burnett, Baltimore, Consolidated Gas, Electric Light & Power Company; Address: "How to Protect Business from Disturbance Caused by Panics"—David R. Forgan, Chicago, president National City Bank; Report of Electric Salesmen's Hand-book Committee—E. L. Callahan, Chicago, H. M. Byllesby & Company.

Temple Parlor, Room No. 3—First Accounting Session—Report of Committee on Uniform System of Accounts—E. J. Bowers, Kansas City, Mo., Kansas City Electric Light Company; Paper: "Accounting School and Education of Employees"—A. L. Holme, New York, New York Edison Company; Paper: "Method of Keeping prepaid and Accrued Accounts"—Franklyn Heydecke, Newark, N. J., Public Service Electric Company; Paper: "Office and Mechanical Appliances, Their Uses, Economies Effected," etc.—H. L. Lohmeyer, Baltimore, Md., Consolidated Gas, Electric Light & Power Company.

Wednesday, 10:00 A. M.—Main Auditorium, Room No. 1—First Hydro-Electric and Power Transmission Session—Address of Chairman of Section—W. N. Ryerson, Duluth, Minn., Great Northern Power Company; Report of Committee on Membership—R. J. McClelland, New York, Electric Bond & Share Company; Report of Committee on Progress—T. C. Martin, Secretary; Report on Turbines (Report being part of National Committee Report on Prime Movers)—J. F. Vaughan, Boston, Stone & Webster Corporation; Paper: "The New Type of Thrust Bearing"—Albert Kingsbury, Pittsburgh.

Lawn Tent, Room No. 2—Second Commercial Session—Report of Committee on Education of Salesmen—George Williams, New York, Henry L. Doherty Company; Report of Committee on Electrical Merchandising—T. I. Jones, Brooklyn, Edison Electric Illuminating Company; Report of Advertising Committee—J. Robert Crouse, Cleveland, National Quality Lamp Division General Electric Company; Advertising for a Small Central Station—N. H. Boynton Cleveland, National Quality Lamp Division, General Electric Company.

Temple Parlor, Room No. 3—Second Accounting Session—Report of Sub-Committee on a Tentative Classification of Accounts Including Balance Sheet and Indicant Accounts—I. L. Bailey, Baltimore, Consolidated Gas, Electric Light & Power Company; Paper: "Handling of Freight Bills"—Albert S. Scott, Chicago, Public Service Company of Northern Illinois; Paper: "Accounting for Replacement of Plant Retired From Service—Frank A. Birch, Philadelphia, Philadelphia Electric Company.

Wednesday, 11:15 A. M.—Main Auditorium, Room No. 1—Second General and Executive Session—Paper: "Central Station Power in Coal Mines"—W. A. Thomas, Pittsburgh, Westinghouse Electric & Mfg. Co.; Paper: "Switching Apparatus for Rural Instalations—E. B. Merriam, Schenectady, General Electric Company; Paper: "Central Stations for Towns of 5 000 Population or Less—J. Edward Kearns, Schenectady, General Electric Company.

Wednesday, 12:45 Noon—Executive Session—Action on Report of Public Policy Committee—Arthur Williams, New York, New York Edison Company; Presentation of Proposed Constitutional Amendments—Frank W. Frueauff, Denver, Denver Gas & Electric Company; Report of Treasurer—W. W. Freeman, Birmingham, Alabama Power Company; Election of Nominating Committee; Appointment of Committee on Resolutions.

Wednesday, 8:30 P. M.—Public Policy Session—Main Auditorium, Room No. 1—Reading of Report of Public Policy Committee; Address by Samuel Insull, President, Commonwealth Edison Company, Chicago; Report of Commission on Resuscitation from Shock—W. C. L. Eglin, Philadelphia, Philadelphia Electric Company; Lecture on Accident Prevention in Public Utilities—J. B. Douglas, Philadelphia, United Gas Improvement Company (Illustrated by Lantern Slides); Musical Exercised During the Evening—N. E. L. A. Section Band; Commonwealth Edison Company.

Thursday, 10:00 A. M.—Second Technical Session—Main Auditorium, Room No. 1.—Report of Committee on Prime Movers—I. E. Moultrop, Boston, Edison Electric Illuminating Company; Report of Committee on Electrical Apparatus—L. L. Elden, Boston, Edison Electric Illuminating Company; Paper: "Switchboard Instruments"—Paul McGahan, Pittsburgh, Westinghouse Electric & Mfg. Co.; Paper: "Latest Developments in Distributing Transformers"—E. G. Reed, Pittsburgh; Westinghouse Electric & Mfg. Co.; Paper: "The Use of the Telephone in Central Stations"—Angus Hibbard, New York, American Telephone & Telegraph Company; Report of Overhead Line Construction Committee — Farley Osgood, Newark, N. J., Public Service Electric Company.

Third Commercial Session — Lawn Tent, Room No. 2—Report of Electricity on the Farm Committee—(a) Eastern States—John C. Parker, Rochester, Rochester Railway & Light Companw; (b) Middle States—C. W. PenDell, Chicago, Public Service Company of No. Ill.; (c) Western States—Stanley V. Walton, San Francisco, Pacific Gas & Electric Company; Report of Committee on Wiring of Existing Buildings—Robert S. Hale, Boston, Edison Electric Illuminating Company.

Third Accounting Session—Temple Parlor, Room No. 3—Report of Sub-Committee on Statistics and Forms—C. L. Campbell, Waterbury, Conn., United Electric Light & Water Company, H. Spoehrer, St. Louis, Union Electric Light & Power Company; Paper: "Obligations of the Bookkeeping Department to the Operating Department"—H. Patterson, Rochester, N. Y., Rochester Railway & Light Company; Paper: "Handling of Bond Coupons"—W. J. Kehl, Richmond, Va., Virginia Railway & Power Company.

Thursday, 2:30 P. M.—Second Hydro-Electric and Power Transmission Session—Main Auditorium, Room No. 1—Paper: "Poles and Pole Preservation"—R. A. Griffin, Chicago, Western Electric Company; Paper: "Lighting Arresters"—E. E. F. Creighton, Schenectady, General Electric Company; Paper: "Developments in Protective Apparatus"—J. N. Mahoney, Pittsburgh, Westinghouse Elec. & Mfg. Co.; Lecture: "The System of the Mississippi River Power Company"—Hugh L. Cooper, Keokuk, Ia., Mississippi River Power Company (Illustrated by Lantern).

Fourth Commercial Session—Lawn Tent, Room No. 2—Report of Committee on Ice and Refrigeration—George H. Jones, Chicago, Commonwealth Edison Company; Report of Committee on Short Cuts in Executing Customers Orders—George C. Holbertson, San Francisco, Pacific Gas & Electric Company; Report of Committee on Steam Heating—S. Morgan Bushnell, Chicago, Commonwealth Edison Company; Report of Nominating Committee; Election of Officers.

Friday, 10:00 A. M.—Third General and Fifth Commercial Session—Main Auditorium, Room No. 1—Report of Rate Research Committee—E. W. Lloyd, Chicago, Commonwealth Edison Company; Report of Street Lighting Committee—John W. Lieb, New York, New York Edison Company; Paper: "Arc Lamps and Recent Developments Thereof"—W. A. Darrah, Pittsburgh, Westinghouse Electric & Mfg. Co.; Paper: "Advantages of Copper Clad Wire for Series Arc Lighting"—T. K. Stevenson, New York, Duplex Metals Company; Report of the Committee on Underground Construction—W. A. Abbott, Chicago, Commonwealth Edison Company; Lecture: "Light and Art"—M. Luckiesch, Cleveland, National Quality Lamp Division, General

Electric Company (Illustrated by Lantern Slides); Address: "Objects of the Society for Electrical Development"—Henry L. Doherty, New York, President of Society.

Third Hydro-Electric and Power Transmission Session—Lawn Tent, Room No. 2—Report of Committee on Receiving Apparatus—M. R. Bump, New York, Henry L. Doherty Company; Report of Committee on Distributing Lines—P. M. Downing, San Francisco, Pacific Gas & Electric Company; Report of Committee on Operation of Water Power Systems—D. B. Rushmore, Schenectady, General Electric Company; Factors Producing Reliability in the Suspension Insulator—A. O. Austin, New York, Ohio Brass Company; Paper: "Transmission Line Construction"—R. D. Coombs, N. Y., R. D. Coombs & Company; Address: "Investigation of Life Hazards of High Tension Lines," by the U. S. Bureau of Standard—Dr. S. W. Stratton, Washington, D. C., U. S. Bureau of Standards; Election of Officers.

Friday, 2:30 P. M.—Fourth General and Third Technical Sessions—Main Auditorium, Room No. 1—Paper: "Transformers and Power Transmission"—H. H. Rudd, Pittsburgh, Westinghouse Electric & Mfg. Co.; Paper: "Railway Loads for Central Stations"—E. P. Dillon, Pittsburgh, Westinghouse Electric & Mfg. Co.; Report of Committee on Award of Doherty Gold Medal—W. F. Wells, Brooklyn, Edison Electric Illuminating Company; Report of Committee on Memorials—T. C. Martin, New York, Secretary; Report of Committee on Constitutional Amendments—Frank W. Frueauff, Denver, Denver Gas & Electric Company; Vote on Constitutional Amendments; Report of Committee on Resolutions; Report of Nominating Committee; Election of Officers; Adjournment.

PERSONALS

Mr. Gano Dunn, junior past president of the American Institute of Electrical Engineers, has recently been elected president of the J. G. White Engineering Company.

Mr. H. C. Donecker, secretary of the American Electric Railway Association, has accepted the position of assistant general manager of the Public Service Railway Company, Newark, N. J. Mr. Donecker has, however, made arrangements which will permit him to continue his association work until after the next convention at Atlantic City in October.

Mr. Allen E. Ransom, formerly manager of the industrial and power department of the Seattle district office of the Westinghouse Electric & Mfg. Company, and later assistant general manager of the Olympic Power Company, has recently accepted the position of manager of the Caldwell Machinery Company, of Seattle, Washington.

Mr. Thos. S. Henderson, sales manager, West Penn Electric Company, First National Bank Building, Pittsburgh, Pa., is interested in obtaining a complete file of manufacturers' catalogues and literature covering all varieties of motors, lamps, devices and appliances that are employed in building up central station loads.

CARD FILE INDEX

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A New Development in Direct-Current Generators—E. P. Dillon. (E.) W-410. Vol. X, p. 410, May, '13.

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The Journal Question Box Nos. 895-

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NEW BOOKS

"The Una-Flow Steam Engine"—Prof. J. Stumpf. 229 pages, 250 illustrations. Published by D. Van Nostrand Company. For sale by THE ELECTRIC JOURNAL. Price, $3.50.

Prof. Stumpf describes, in a very graphic manner and in abundant detail, the very unique and useful type of steam engine developed by himself. As suggested by the title, the steam flows in a constant direction from inlet valve to exhaust ports, avoiding the variation in temperatures which produce cylinder condensation. This excellent feature has a valuable supplement in the form of valveless exhaust ports controlled by the travel of a piston. The author treats first of the thermal and constructional features and then takes up elaborately the results of numerous tests. As the book indicates, this type may be adapted to all of the general requirements in steam engine practice, and the locomotive and stationary locomobile types of self-contained unit presents a promising opportunity. Abroad, this construction has met with marked favor, and several manufacturers in this country have undertaken to introduce the Stumpf Engine in the American market. While the steam turbine has probably overshadowed, to a large extent, its growth in the field of stationary prime movers, there are other important uses in which it is expected to maintain a position of much value, such as locomotives, self-contained units, compressors, winding and rolling mill engines, etc. The book may profitably be examined by engineers and business men engaged in the use of power. E.D.D.

"Coal—Its Consumption, Analysis, Utilization and Valuation"—E. E. Somermeier. 167 pages, 8 illustrations. Published by the McGraw-Hill Book Company. Price, $2.00.

This is a condensed and practical treatise on the subject of coal, dealing with the various chemical phases as indicated by the title. The information embodied is important to every large consumer of coal, and a great many points are brought out, such, for example, as the possible bearing of the ultimate composition of the coal upon its burning qualities or characteristics, certain essential observations in sampling and analytical determinations, etc. Too frequently such factors are overlooked or else unappreciated in the ordinary tests or investigations of coal. The book is concluded by a summary of the leading coal fields of the United States. E.D.D.

THE
ELECTRIC JOURNAL

Vol. X JULY, 1913 No. 7

The Tendency in Contact Design

The article in this issue of the JOURNAL on "Electrical Contact Resistance" by Mr. F. W. Harris, deals with a matter little thought of, but, as well shown, of fundamental importance in the design of switching apparatus. The investigations described by Mr. Harris show results doubtless quite contrary to those generally expected. These may be summarized briefly as follows: "The resistance between clean contacts maintained at a given pressure is practically independent of their surface condition." This means that comparatively clean contacts, whether new or burned, will present practically the same resistance, so long as they are not burned away sufficiently to reduce the initial pressure.

The following contact designs are commonly employed:—(a) laminated brush, found in the better carbon breakers, also in many oil circuit breakers; (b) finger type of contact, well illustrated in the ordinary drum controller, which is a rubbing contact, and also frequently found in oil switches; (c) the butt type of contact, particularly used for arcing tips with oil switches and where heavy service, such as frequent motor starting, is involved; (d) a further design, employing a rolling contact and heavy pressure at the end of travel between surfaces resembling the plain butt design.

In comparing the butt contact with the other designs, its simplicity is strongly advocated as its best justification. In order to carry large currents, pressures excessive for ordinary mechanisms are required, hence the application of the butt contact to such service has not received the same approval as the laminated brush, which has the additional advantage of being self-cleaning. The same advantage is enjoyed by the sliding contact design, though it is probably not so well adapted to carrying very large currents as the laminated contact. The butt contact is, however, a very useful ally of the laminated contact, and also of the sliding contact, as an arcing tip. The combination of the butt contact with the laminated or sliding form is found in the best modern practice. This is because the self-cleaning qualities of the laminated or sliding contact designs recommend them, especially where large currents are to be carried continuously, and the ready replacement features are in the favor of the butt contact, where renewal is likely. A butt design arranged for sliding contact as a means for obtaining self-cleaning has also received some favor. The general tendency is to employ the laminated and sliding contacts instead of the simpler and, otherwise apparently desirable butt contact for heavy service, inasmuch as the butt design is particularly adapted to light service, rather than to heavy service, because of its failure to be self-cleaning. K. C. Randall

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High Efficiency Illumination

The last few years have witnessed a remarkable increase in the use of electric current. One of the most important factors contributing to this increase has been the development of high efficiency lighting units for all purposes. The gradual improvement of one system after another has set new standards for commercial and industrial illumination. Not only is this so, but the introduction of these units has been responsible for an investigation into the results of artificial illumination that has demonstrated conclusively its importance as a factor in production. Efficient illumination is today accountable for a marked increase in the output of industrial establishments of all kinds.

In regard to cost, it is an easy matter to prove that the scientific installation of any of several high efficiency illuminants, replacing a system of lighting used before the introduction of high efficiency lamps and illuminating engineering, will more than pay in increased production all its operating and maintenance expenses. An increase in the efficiency of lamps, when this is taken into consideration, would seem to be a matter of secondary importance. Still, since so much has been accomplished in raising efficiency in the last few years, it is but natural to look forward to better attainments. When, therefore, any modification of an existing standard is introduced, which tends to raise the standard still higher, or to extend its field of usefullness, it must prove of interest from a commercial as well as from a scientific standpoint.

The article appearing in this issue by Dr. J. C. Pole, an acknowledged authority on illumination, well merits the attention of all who are interested in the development of electric illumination. The quartz lamp, while based on the same principle as the well known Cooper Hewitt mercury vapor lamp, possesses some essential differences, the most pronounced of which is the substitution of a short tube of pure fused quartz or silica for the familiar long tube of lead glass. While the light given off possesses practically the same qualities as the glass tube light, and the impression on the eye is similar, the higher operating temperature produces a continuous spectrum in addition to the discontinuous spectrum given by the standard Cooper Hewitt lamp. The light of the quartz lamp, therefore, has a larger proportion of yellow and some orange rays.

Since the light giving element or burner is theoretically indestructible, as neither the mercury nor the quartz is consumed in the process of operation, this lamp would seem to be an improvement over any other large unit in the simplicity of maintenance. Assuming that it is mechanically rugged in construction, it might be said to belong in the same classification as the incandescent lamp so far as trimming is concerned. In outward appearance the lamp resembles an arc lamp since the auxiliary is surrounded by a cylindrical housing and the quartz burner is enclosed in a lead glass globe.

The quartz lamp is a higher candle power unit and is also an out-door type of lamp. It would seem, therefore, that there is a very wide field for it, especially for use in large enclosures, high roofed industrial plants, rolling mills and erecting shops and for the lighting of yards and docks. A. D. CHILDS

Hydro-Electric Conservation

The article by Mr. Morris Knowles in this issue serves to call attention again to that fundamental difference between power derived from steam and that obtained from hydro-electric plants which was pointed out in an editorial in the JOURNAL, in January, 1910. In brief, it was stated that there is this all important difference between a fuel bed and a water supply as a source of power; the former, once used, is lost for all time; the latter, so long as it remains unused, is lost for all time. The former can wait *in statu quo* indefinitely; the latter should be developed to its fullest legitimate extent *instanter*. In other words the principal of conservation calls for immediate development of our water powers to their fullest extent.

However, in actual practice, the principle of conservation of natural resources cannot and does not operate so as to suspend the law of supply and demand, and so long as power can be produced more cheaply by burning fuel than it can from our streams, just so long will coal continue to be consumed for the production of power, and the streams left undeveloped.

The great barrier, of course, to the extended use of our streams as a source of power is the neecssity, on the one hand, for a uniform, continuous supply of power to meet our modern conditions and, on the other hand, the tremendous fluctuations of stream flow that may cause the suspension of power supply due to either too much water during flood season or too little during draught. Any steps, no matter what, which will tend to eliminate these fluctuations will also make our streams better power producers.

If, on account of either high water or low water, it is necessary to duplicate a water power with a steam reserve, it is evident that the water power development is justified only when the yearly fixed charges on the cost of that water power are less than the value of the coal which would be burned in the steam plant if the water power did not exist. An analysis will show that for most cases of this kind, it is not commercially practicable to put into water power an amount much in excess of one hundred dollars per kilowatt, and often the amount may be as low as one-half this figure. The exact amount, of course, depends largely upon the load factor and coal cost, but for public service utilities where fuel is not unduly expensive, the permissible cost of the water power plant will come somewhere within this range. It is evident, therefore, to thoes who are familiar with the usual costs of hydraulic development, that for such conditions water power is often an expensive luxury.

Mr. Knowles calls our attention to the fact that there are factors involved in the conservation of our streams other than power development. Navigation, irrigation and most of all, in view of the late devastation in Ohio and Indiana, the prevention of floods, are considerations of tremendous weight when it comes to making a comprehensive study of our streams and their development. It is a significant fact that many of the steps suggested for the improvement of our streams, in the interests of irrigation, navigation and flood prevention, particularly the establishment of reservoirs at head-waters, will better the conditions so far as power supply is concerned. To put this same proposition in another way, it is perfectly legitimate to charge a part of the cost of developing our streams for power purposes to interests other than those concerned purely with the development of power.

The conservation of our fuel supply demands the development of the streams and the law of supply and demand acts against such development so long as its total cost i scharged to power supply alone. It is evident that the situation is one which requires close and thoughtful coöperation. It behooves electrical engineers, therefore, to take heed to Mr. Knowles' plea for the coöperation of all those interested in the development of our streams.

P. M. Lincoln

THE COOPER HEWITT QUARTZ LAMP

JOSEPH C. POLE

THE quartz lamp, in the broadest meaning of the word, is a vacuum arc lamp, the vacuum container of which is made of fused quartz. At present, however, the term is applied only to mercury arc lamps operating at a very high vapor temperature, in quartz tubes, although it is possible that the mercury will later be superseded by some other metal or an amalgam having a greater efficiency and a better color effect.

As generally known, the voltage consumed in an arc can be divided into two parts, each one distinguished from the other in a physical and technical sense; the potential drop on the *electrodes* and the drop in the *vapor column.* Unlike ordinary types of arc lamps, especially those with carbon electrodes, the energy consumed at the *electrodes* in the mercury arc contributes practically nothing to the generation of light, only that part of the voltage taken up in the *vapor column* being directly used in producing light. Hence, the efficiency of a mercury vapor lamp depends largely on the ratio of the drop of potential in the vapor path to the potential difference across the arc and, naturally, the tendency of the designer is to make this ratio as great as possible. As Dr. Hewitt* has proved by extensive investigations, the drop of potential per inch in the luminous column of a mercury vapor lamp depends upon the vapor pressure, growing steadily with increasing pressure or temperature of the vapor. Thus, with a given supply voltage in a mercury vapor lamp, one has the following alternative means of increasing the percentage of the voltage transformed into light:—

a—To make the vapor pressure, and accordingly the drop of potential per inch of luminous column, small and the tube very long.

b—To increase the vapor pressure radically and shorten the luminous column.

Each of these two methods has its advantage. The first one forms the underlying principle of the standard Cooper Hewitt lamp which, as the tube is made of common glass and therefore will not stand high temperatures, is hardly ever run at higher pressure than ⅛ inch of mercury column. The very refractory quartz glass, however, which does not soften below 2 500 degrees F., permits the application of temperatures that drive the vapor pressure above that of the atmosphere and raise the drop of potential per inch of

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*P. Cooper Hewitt, *Electrician*, London, Vol. 52, p. 447, 1904 the luminous column to 30 and more times the magnitude of the standard Cooper Hewitt lamp. Thus, the low pressure mercury vapor lamp and the quartz lamp, in spite of having been built upon the same physical principles, still represent two almost diametrically opposite principles of modern illuminating engineering. One possesses the greatest area of primary luminous surface with a consequent small intrinsic brilliancy and so low a temperature that it may be considered near the ideal of scientists' "cold light"; while the other has a small radiant body giving a very concentrated light and operates at temperatures probably exceeding the highest ever attained up to a few years ago.

The method of transforming the energy into light is also different in the two types:—

In the standard Cooper Hewitt lamp, the light is generated by luminescence of the ionized vapor, in a manner similar to that obtained by the electric discharge in a vacuum (Geissler) tube, and consequently it gives a *discontinuous spectrum* characteristic of the chemical nature of the gas, being that of mercury.

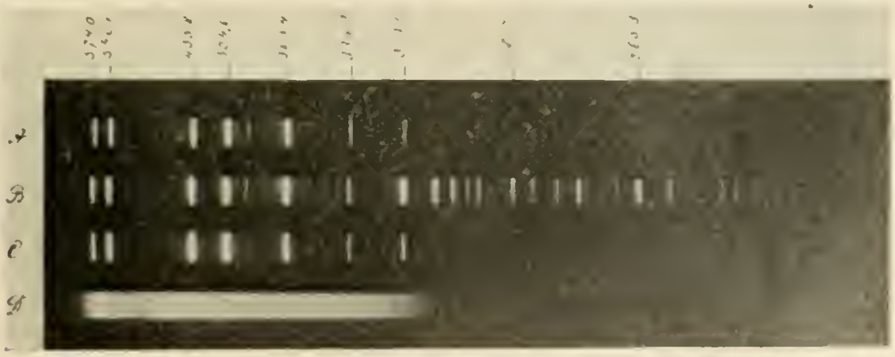

FIG. 1

A—Spectrogram of standard Cooper Hewitt lamp. *B*—Spectrogram of Cooper Hewitt quartz burner. *C*—Spectrogram of Cooper Hewitt quartz lamp with glass globe. *D*—Spectrogram of sunlight.

With higher pressure to this luminescence is added the radiation of mercury vapor heated to incandescence. The latter emits, like all incandescent bodies, a *continuous spectrum*, and it is due to this circumstance that the light of the quartz lamp also contains, besides the preponderant yellow, blue, green and violet lines of the mercury spectrum, red and orange rays, the latter being increased in proportion to the increase in the vapor temperature. Bessides the visible rays, the wave length of which extends down to about 390.10 ^{6}mm, the mercury arc is very rich in light of shorter wave lengths, the so-called ultra-violet rays. In the standard Cooper Hewitt lamp (See Fig. 1 *A*), these rays are absorbed by the glass of the container. The quartz glass, however, transmits, according to its thickness, light of 180-240.10^{-6}mm. (See Fig. 1 *B*). These ultra-violet rays are chemically and physiologically very actinic and are under certain conditions injurious to the eye. Therefore, where quartz lamps are used for general illumination, the ultra-violet rays are eliminated by surrounding the vacuum container by a glass globe which, even when of perfectly clear glass, cuts out all injurious rays, as shown by the spectrogram *C*, Fig. 1. The light of a Cooper Hewitt quartz lamp with globe contains even less ultra-violet rays than ordinary daylight, which is evidently absolutely harmless to the eye.

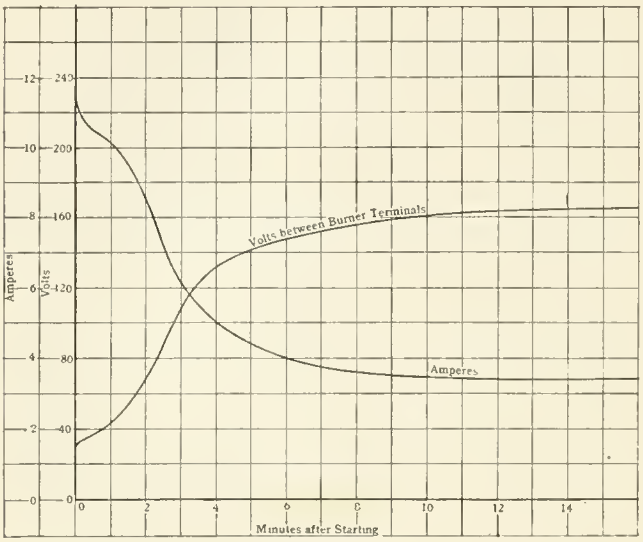

FIG. 2—STARTING CHARACTERISTICS OF A 220 VOLT COOPER HEWITT QUARTZ LAMP

Often the quartz lamp is used for the sole purpose of generating ultra-violet light; then of course, no glass is inserted in the path of the rays and the exposed object is brought as close as possible to the arc, as even the air absorbs ultra-violet rays to a great extent.

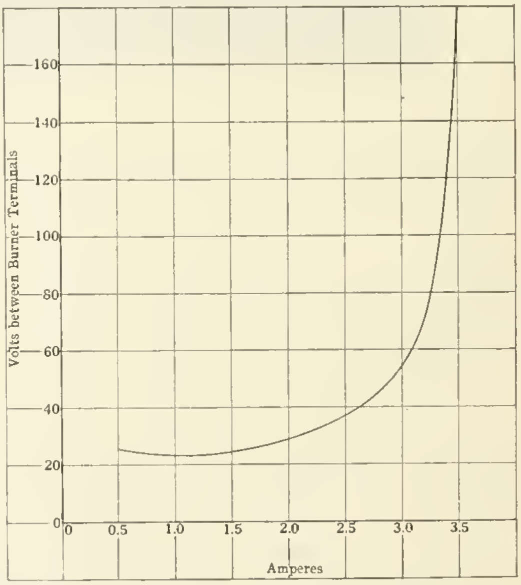

FIG. 3—STATIONARY CHARACTERISTIC OF A 220 VOLT COOPER HEWITT QUARTZ BURNER

The vapor pressure that determines the voltage between the electrodes of a quartz burner depends upon the ratio of the electric energy supplied to the burner to the heat carried away from the electrodes where vaporization takes place. As the burner has a considerable heat capacity there is a lag between the electric current and the burner voltage. When a cold quartz burner is started, the vapor pressure is at first very low, which fact may be easily perceived by the appearance of the light. The luminous vapor fills the entire cross-section of the tube and is of the pale blueish-green color that is characteristic of the low pressure Cooper Hewitt lamp. The drop of potential across the cold burner of the 220 volt lamp, described below, is, for instance, about 25 volts, compared with a voltage of 165 in the lamp under normal operating conditions. The current during the starting period is limited only by the series resistance. Subsequently, due to the electric energy supplied, the vapor pressure and the burner voltage increase and the current decreases until it reaches the stationary value. This process, illustrated by the "starting characteristic", Fig. 2, is accompanied by the concentration of the light in the center of the tube in a thin dazzling path, assuming a whiter color with the visible gain of red and orange rays.

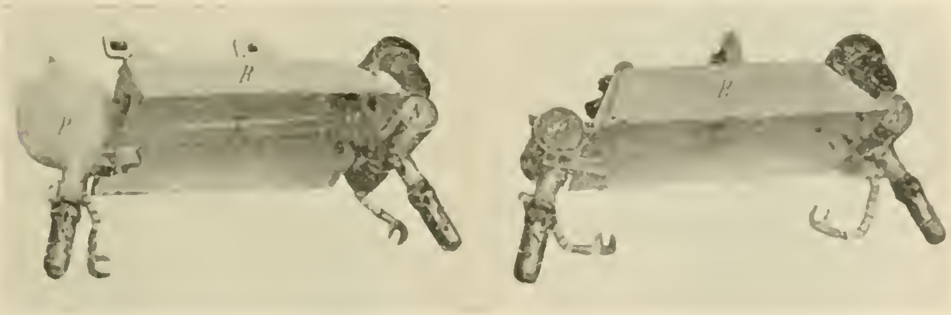

FIG. 4. (*a*) FIG. 4 (*b*)

FIG. 4—*a*—220 VOLTS, 3.3 AMPERE QUARTZ BURNER. *b*—550 VOLT, 2 AMPERE QUARTZ BURNER

The lag between a variation in supply of energy to the burner and the change of the vapor pressure has the consequence that, with a sudden change of the supply voltage, the entire *voltage difference is at the first instant consumed by the series resistance and finally by the burner.* This very simple phenomenon, although seeming somewhat strange, can easily be understood from the "stationary characteristic" (volt-ampere curve under stationary conditions) of the quartz lamp, Fig. 3. As the characteristic at higher vapor pressures is a very steep and almost straight line, a change of from 10 to 15 percent of the burner voltage has hardly any effect upon the current. The latter is practically constant, unless the cooling condition is changed, as, for instance, if the lamp should be better ventilated. At the instant of a sudden rise of the line voltage, the burner voltage does not respond at all, as the vapor pressure, on account of the heat capacity of the vacuum container, remains unchanged for a short time. Hence, the entire excess of the supply voltage is, at the first instant, taken up by the series resistance and results in a sudden increase of the current. Gradually, due to the increased energy input, the burner gets hotter, the burner voltage increases and the excessive current drops until, finally, the current settles to practically the same value it had before. The final effect of the change of the supply voltage is then merely an increased burner voltage. An analogous, but opposite, change takes place with a sudden decrease of the line voltage.

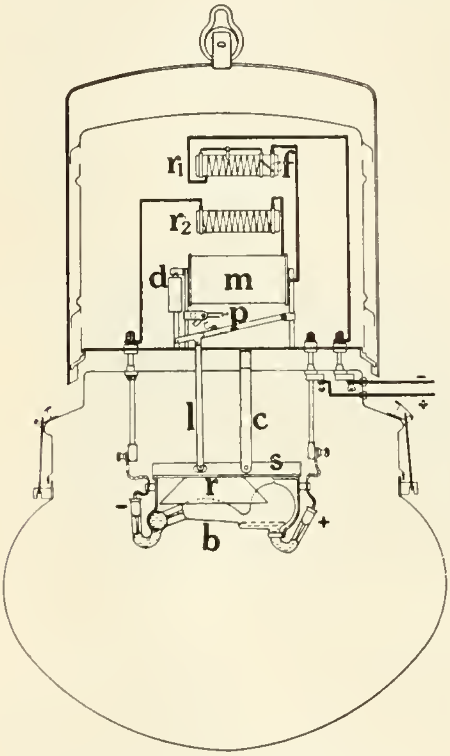

FIG. 5—DIAGRAM OF THE 110 VOLT 3.8 AMPERE COOPER HEWITT QUARTZ LAMP

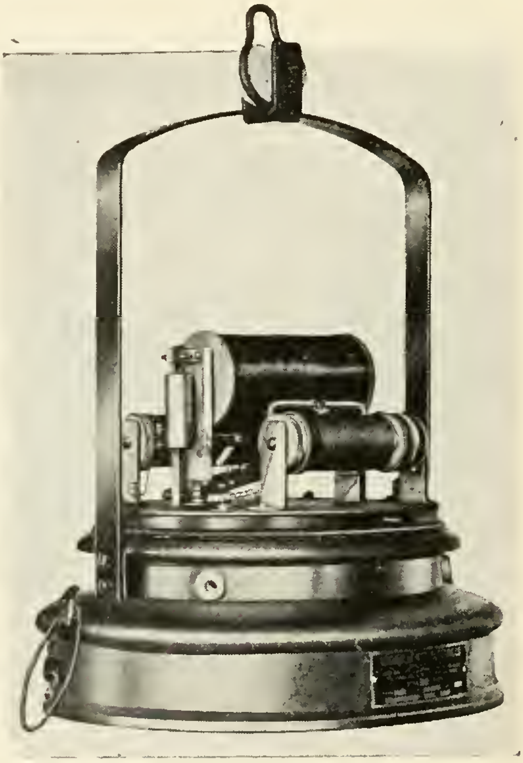

FIG. 6—AUXILIARY OF THE 110 VOLT, 3.8 AMPERE COOPER HEWITT QUARTZ LAMP

A series resistance is, therefore, always necessary with quartz lamps, not only for limiting the current at the starting or with a fluctuating line voltage, but also for regulating properly the burner voltage (vapor pressure) and making the lamp adaptable to a wider range of supply voltages. A series inductance, for steadying the arc, is usually added, although with the high pressure mercury arc it is not absolutely necessary. In the commercial lamp, a glass globe is provided to prevent too quick a dissipation of heat from the burner and to absorb the ultra-violet rays. If the lamp is to be automatic, as generally required by commercial conditions, a starting device, usually consisting of an electro-magnet coupled with the movable burner, is added.

The Cooper Hewitt quartz lamps put on the market up to the present time are for multiple connection on direct-current lines. They may be operated, however, from alternating-current lines through the medium of the Cooper Hewitt rectifier. Vacuum containers for a direct-current Cooper Hewitt quartz lamp, are shown in Fig. 4. The essential part is the luminous tube *T* terminating in two enlargements *P, N;* mercury contained in either enlargement forms the two electrodes which receive the current through small seals S_p, P_n. The joint of the luminous tube to either electrode chamber is contracted to prevent flickering of the arc and to regulate properly the mercury level. The vacuum container is fastened to a reflector-holder of white enameled sheet iron by means of thin metal straps.

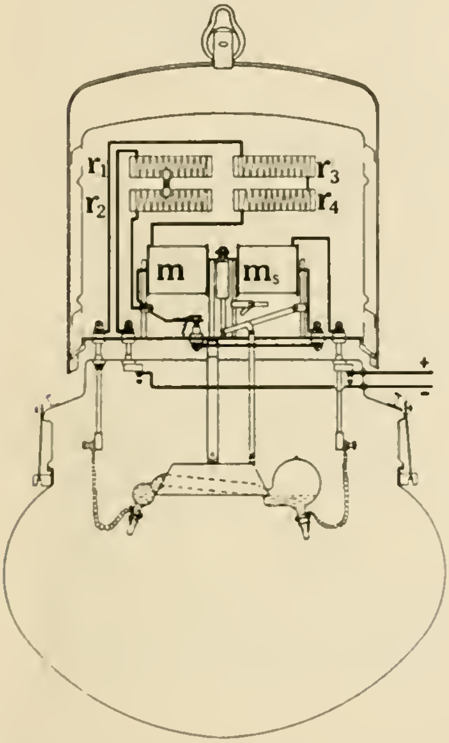

FIG. 7—DIAGRAM OF THE 220 VOLT, 3.3 AMPERE COOPER HEWITT QUARTZ LAMP

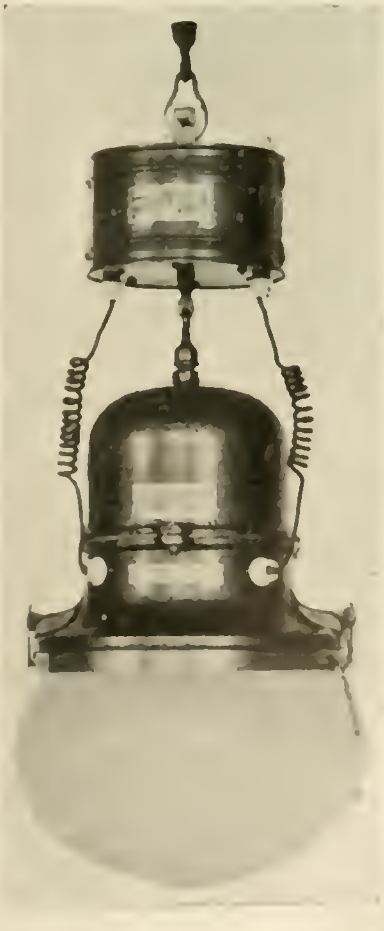

FIG. 8—FUME-PROOF COOPER HEWITT QUARTZ LAMP

The arc is started by momentary contact between the two electrodes. For this purpose the burner holder is pivoted and tilted in starting. The automatic starting device may be arranged so that when current is not flowing, the burner rests in an inclined position with its two electrodes short-circuited and, to form an arc, is lifted to its normal running position with the two electrodes separated. With another system the position of rest of the burner is identical with its running position and, for starting, the electrodes are brought together for an instant and then separated. The first method, preferable with short burners, is used in the 110 volt lamp described below, while the second is employed on the 220 and 550 volt Cooper Hewitt quartz lamps.

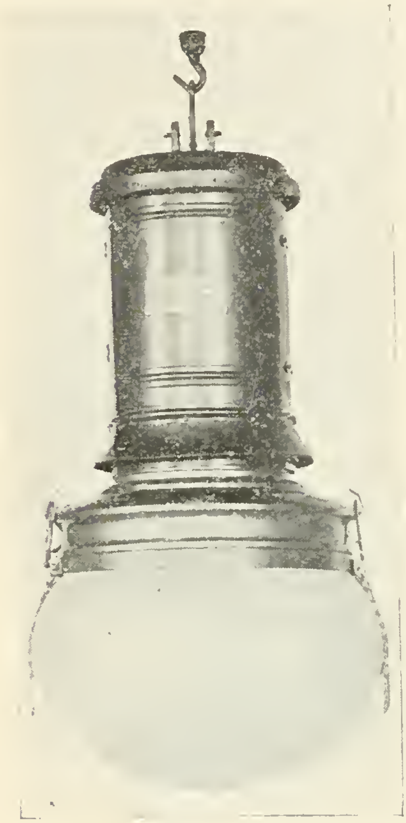

FIG. 9—550 VOLT, 2 AMPERE COOPER HEWITT QUARTZ LAMP

A Cooper Hewitt quartz lamp designed for connection in multiple on 110 volt direct-current circuits is shown in Figs. 5 and 6. *b* is the quartz burner similar to that in Fig. 4*a*, except that the luminous part is shorter. The burner holder is pivoted in a support *c* and by a bracket hooked on the tilting lever *l*, which again is linked to the movable iron armature of an electro-magnet *m*. In order to avoid sudden shocks to the movable parts, a dashpot *d* is connected with the armature. A small movable permanent magnet *p* is suspended above the armature; it locks automatically the tilting device if the polarity at the lamp terminals is reversed and so protects the burner. Two resistance coils r_1, r_2, one of them being equipped with a fuse *f* and a sliding contact for regulation, complete the auxiliary apparatus. The ventilated canopy, the insulated hanger and a ring holding the glass globe are similar to those used with some ordinary types of arc lamps.

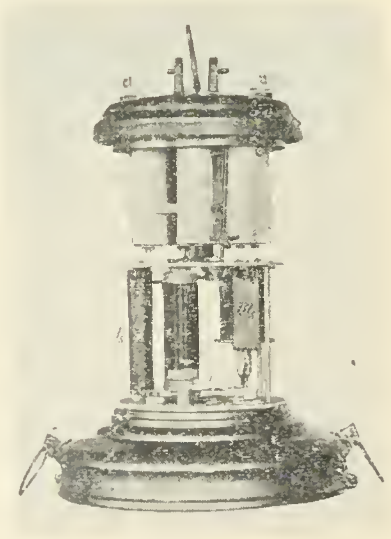

FIG. 10—AUXILIARY OF THE 550 VOLT, 2 AMPERE COOPER HEWITT QUARTZ LAMP

The burner, magnet and resistance coils all are connected in series, and the burner, in its position of rest, is inclined, so that the two mercury electrodes are in contact. When the line switch is closed the short-circuit current magnetizes the solenoid *m*, the movable armature, and with it the burner, are turned until the contact between the electrodes breaks and the arc starts. As long as the current flows through the lamp the burner is held in its running position by the electro-magnet. The fuse wire *f* will withstand the heavy current during the starting period of the lamp, but will in about one minute be fused by the additional heat generated in the resistance spool r_1, if, for any reason, the mechanism sticks and the burner continues to receive current.

A lamp for multiple connection to 220 volt direct-current circuits, with the burner and the general appearance very similar to the one described above is shown diagramatically in Fig. 7. Here an extra tilting mechanism is used for striking the arc. For starting, the two electrodes are brought in contact by the movable armature of a shunt magnet M_s. At the moment of the moment of the short-circuit between the electrodes, the series inductance coil *m* operating an automatic cutout, is energized, and interrupts the circuit of the shunt magnet so that the burner is lighted and drops back to its original position. Two pairs of series resistance coils, r_1, r_2, r_3, r_4, equipped with sliding contacts, complete the mechanism.

For locations subjected to corrosive fumes, the auxiliary apparatus is divided into a part containing the shunt magnet and an automatic cutout for striking the arc, and an auxiliary comprising the resistance and inductance coils, Fig. 8. The joints in the housing holding the movable parts are reinforced by asbestos packings.

The Cooper Hewitt quartz lamp for multiple connection on 550 volts direct-current circuits, as shown in Figs. 9 and 10, is very similar in principle to the 220 volt lamp, although entirely different in construction. The starting mechanism consists also of a shunt magnet M_s and an automatic cutout, but on account of the high voltage an extra resistance R_s is used for the starting circuit and, as 500 volt lines usually have a very fluctuating voltage, a second inductance is added. The extra series resistance required is formed of 6 spools and is mounted on top in the auxiliary.

The remarkable abundance of ultra-violet light in the Cooper

Hewitt quartz lamp naturally suggests its use for medical and industrial purposes. Among the latter, for instance, are the sterilization of water, acceleration of chemical processes, bleaching, etc., where before, less efficient and much more intricate devices for generation of ultraviolet rays have been used. For these purposes a simple and convenient stand, Fig. 11, has been developed, comprising a large reflector holder for the quartz burner and an auxiliary with series resistance-inductance. The quartz burner, either of the above described 110 volt or 220 volt type, but without attached reflector, is suspended below the reflector holder. The arc is started by tilting the burner by means of a handle protruding from the holder. The stand is mounted on rollers, is adjustable and permits the location of the burner directly and closely above the exposed object. The reflector holder covers the entire burner to prevent the light from escaping sideways, hut has hinged cover permitting easy access to the burner. In conclusion some technical data is presented on the above described types.

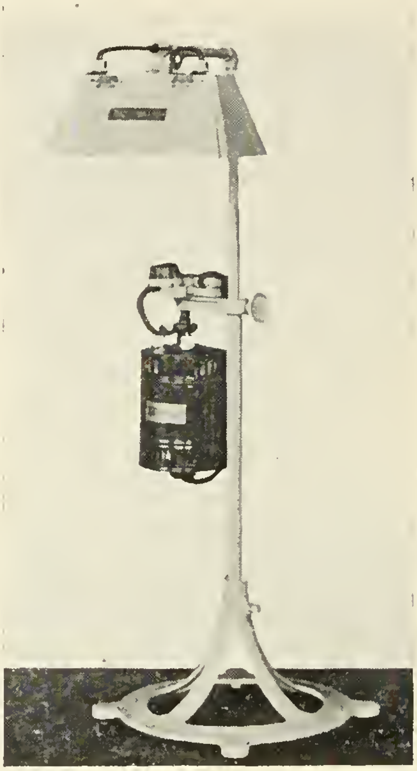

FIG. 11—LABORATORY STAND FOR COOPER HEWITT QUARTZ LAMP

TECHNICAL DATA ON QUARTZ LAMPS

Cooper-Hewitt Quartz Lamp Type	Y	Z	X
Nominal supply voltage.	110	220	550
Full range of supply voltage.	100-125	200-250	450-625
Average current.	3.8	3.3	2.0
Maximum burner voltage.	90	170	345
Candle-power mean hemispherical with clear glass globe.	1 000	2 400	3 500
Commercial efficiency, watts per mean hemispherical candle at nominal line voltage.	0.42	0.30	0.31

HYDRO-ELECTRIC DEVELOPMENT AND WATER CONSERVATION

MORRIS KNOWLES

Consulting Engineer, Pittsburgh, Pa.

THE professional interests of electrical and hydraulic engineers are not far apart. The former have the good fortune to be living and working in the Electrical Age—an age in which every day sees some new and amazing service supplied by this invisible power.

THE ELECTRICAL AGE

Over two billion dollars was spent during the past year in the United States for electrical apparatus, conveniences and transmission service; that is over twenty dollars for every man, woman and child. How thoroughly our very existence is linked with electric power is clear at once if we think of what a part the street car, electric light, telephone and telegraph play in our daily acts. Electrification of railroads has grown apace, promising great things for the future; already it has made possible achievements undreamed of a few years ago. The tubes under the rivers bounding Manhattan Island and the great Pennsylvania station at New York City could not be, without electricity. That magnificent achievement of the Grand Central Terminal, the lowering of the tracks and the reclamation for stores, offices, etc., of twenty city blocks over the railroad yards in the very heart of New York City, all this would be inconceivable without the substitution of the clean, silent, motor for the smoking, steaming, noisy locomotive.

The strongest appeal to the imagination, however, is made by the commercial success of electrical fixation of nitrogen from the air. This and the recent production of calcium cyanamide are most important contributions to agriculture and the fertilizer industry. That the gloomy prognostications of those who have threatened us with starvation, because of the predicted failure of the Chilean nitrate beds, should be overthrown by the use of our cheapest and most plentiful natural resource—air—this is indeed a modern miracle. Electrolytic chlorine and hypo-chlorites are successfully solving important problems, viz.—cheap and efficient disinfection of sewage and polluted waters, and to the same problem we may yet have occasion to apply electrically produced ozone and ultra-violet light.

Engineers, metallurgists, chemists, physicists—all are devot-

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*Revised for the JOURNAL by the author from an address before the Pittsburgh meeting, American Institute of Electrical Engineers, February 8, 1913.

ing their energies to finding new and important fields for electrical applications. But one other factor has similarly advanced in importance and that has been the increased cost of fuel with the gradual exhaustion of our coal, oil and gas deposits, and threatened limiting of electrical growth because of the increased cost of power. Of the seriousness of the decreased fuel supply, if electric power were to be entirely dependent upon steam generation, there can be no doubt; although there may be differences of opinion as to how long these fuel resources will last. Conserve them as we will they are absolutely limited in quantity. They must at last be exhausted and the use first of those which are easiest to obtain and cheapest to exploit must result in increased cost as more expensive deposits must be worked. On the other hand, any method of power development that is not dependent upon a decreasing natural resource will become accordingly valuable.

THE HYDRO-ELECTRIC AGE

This is where the interest of the hydraulic engineer is at once aroused and the progress that has been made in hydro-electric development and power transmission is therefore of the very greatest importance; perhaps in some ways more so than the more spectacular advances in the diversified application of electricity itself. As it has been said that we are now living in the Electric Age and as this requires cheap power to maintain its growth, it is equally true that we are entering upon and have arrived at an Hydro-electric Age. Here is a method of power development as eternal as the sun itself; throughout all the years to come water will be raised by solar energy, precipitated upon the land, to descend again into the ocean; moreover, it lies within our power to make the flowing supply uniform and dependable.

As high voltage transmission and other developments make possible delivery of this power exactly where it is needed, a new elasticity is given to industrial development by allowing manufacturers to move nearer to markets or to raw materials. The possibility of using hydro-electric power for mining coal at less cost than by steam power is strikingly illustrated by the development now being carried out on New River, West Virginia, which will sell about half its output to coal companies for operating mine machinery. The Cheat River hydro-electric development, right in the heart of the Connellsville region, will compete with local coal in supplying power for lighting, traction, and industry in the surrounding towns and even to nearby coal mines.

WHAT WE HAVE

Seventy million million cubic feet of water annually is running off to the sea from the surface of this country, enough to generate two hundred and fifty thousand horse-power throughout the year for every foot of fall between the place of precipitation and the ocean. Various estimates have stated that the commercial, developable power is about 37 000 000 horse-power, while the ultimate capacity of our streams is about 230 000 000 horse-power. In our state of Pennsylvania, we are now developing 300 000 horse- power by water, while the potential energy of the falling water is over ten times this amount. As Prof. P. M. Lincoln has stated with regard to dependence upon this form of power:—

"The first requisite is continuity of service. This means constant supply of water. If a supplemental steam plant is necessary to supply the power demand during low water, it is hardly ever a good investment to pay the fixed charges upon the cost of both water and steam plants, in order to save the use of coal for a portion of the year only. The solution is storage at head waters, which will not only prevent floods, but will also make for a constant supply of water for power purposes."

WHAT WE ARE DOING

It is worth while to look at the subject in a broader way rather than considering power potentialities alone. The mind is astounded by the possibilities of power, irrigation, water supply and waste disposal which the seventy million million cubic feet of water represent. Only about one-seventh of one percent is used for domestic, industrial and public water supply, and yet we have scarcely a large city in the country that can secure its share of water in such condition that expensive purification is unnecessary. About two percent is used for irrigation, and perhaps five percent is partially used for navigation. About 6 000 000 horse-power is generated from some five percent of the water. We are wasting about 1 500 000 horse-power at the government navigation dams alone. Finally, about 90 percent of the water flows away, not only without being used, but doing enormous damage by floods.

Our veiw has been too narrow. These navigation dams are a case in point. Hundreds of millions of dollars have been spent in canalization of rivers and yet with few exceptions, no attempt has been made to correlate this expenditure with the conservation of all the usefulness in the water. Clinging to a narrow interpretation of the Constitution and maintaining that the government could properly expend money on rivers for navigation only, scores of low dams have been built on navigable rivers, when fewer high ones would have served navigation just as well and have made possible the development of industry and the conservation of fuel supply, by creating hydro-electric power.

The Deep Waterways Board, which investigated the Great Lakes Atlantic Ocean Waterway, in 1900,—found that high lifts would save in cost and in time between terminals; with slight lessening of annual traffic capacity which is not of importance, considering the insufficient development of commerce.

Signs of improvement, however, are visible. The possibilities of arriving at coöperative agreements under which the same dam can be used for more than one purpose is important. Thus, on the Warrior River in Alabama, a dam and flight of locks 63 feet high has been authorized to take the place of five low dams and locks, in order to permit power development, and incidentally to effect a total saving of almost a million dollars. At Hales Bar on the Tennessee River, on the Coosa River in Alabama and at Keokuk on the Mississippi, private companies have been authorized and are constructing locks and dams for both navigation and power. On the Mississippi River, between Minneapolis and St. Paul, the government is now building a lock and dam of 30 feet lift, at which power will be developed.

In other governmental departments the same tendency is shown, as in the Reclamation Service, where power is generated at a number of irrigation dams, and at the Panama Canal, where a water power plant is to be supplied from Gatun Lake. There even appears some hope of getting away from the idea that the government can improve rivers for navigation only, as is strikingly indicated by President Taft's advocation of the control of the Mississippi River floods under the general welfare clause of the Constitution.* In an address before the National Rivers and Harbors Congress, December 4, 1912, the President declared flatly that:—

"The hanging of the expenditure of forty or fifty millions that is needed to make the Mississippi River safe, on the resulting benefit to navigation was a pretense," and added:—

"Under the Constitution we can expend money from the

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*The same thought is evident in the resolutions passed at the National Drainage Congress, St. Louis, April 12, 1913, viz.:

Whereas, in view of the appalling and ever recurring disasters caused by floods, which have destroyed life and property throughout the United States, and which is emphasized by the recent and widespread calamity brought upon our citizens by the floods which have devastated Ohio, Indiana, Illinois and adjoining States, and which devastating floods are now moving

Treasury of the United States for the general welfare, and that would seem to include the avoidance of danger, if it affects so large a part of the country that it may be said to affect the whole country, and if its avoidance involves such large expnditures that we cannot possibly look to the State to meet the requirement."

WHAT WE NEED

All these are partial measures only. What is needed is something more comprehensive. Such a great national matter can be solved in a great national way only, and with the realization that we have a welfare clause in the Constitution as well as a commerce clause. We must have first complete knowledge, gained by comprehensive study on such a scale that the information necessary to judge as to the best utilization of all the water resources throughout the land can be obtained, treating each system as a unit from the source to the mouth.

Finally, methods must be devised to carry out this policy; some works may be constructed by states and some, if we have a more comprehensive idea of national expenditure, by the United States Government. But so long as we continue in the belief that the social and economical structure of society and the interests of the public are best promoted by encouragement and stimulation of private initiative—development by intelligent self-interest—and so long as our state and national governments lag behind the needs of the people in expenditures for these purposes, so long must

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southward throughout the Mississippi Valley, threatening destruction to life and property all the way to the Gulf of Mexico, and

WHEREAS, we believe it to be an equally proper function of the government of the United States, under the Welfare Clause of the Constitution, to take adequate measures to control the water resources of our country, so as to protect the life, health and property of our citizens from the controllable forces of nature, as it is to protect our citizens from the attack of a foreign force; now, therefore, be it

Resolved, by the National Drainage Congress, in which thirty-nine States are represented in convention assembled, that we respectfully petition the immediate consideration of adequate provisions for flood control for the regulation and control of stream flow, and for the reclamation of swamp and overflow lands and arid lands, and in furtherance thereof we pray that in your wisdom you create a body which will put in effect at the earliest moment possible such plans, in conjunction with the several States and other agencies, as will meet the needs of the several localities of the United States, and we believe the most effectual and direct mans will be the establishment of a Department of Public Works with a secretary in charge thereof, who shall be a member of the President's cabinet. Be it further

Resolved, that the wide scope of the problem of flood water control, affecting practically all the States of the Union, can best be conducted under the immediate supervision of the President of the United States in the exercises of such authority as is conferred upon him by the Congress of the United States.

we offer opportunities to private capital to make moderate profits under governmental regulation, by investing in the dvelopment of projects consistent with this policy. Secretary Fisher of the Interior Department strongly commended this policy in his Annual Report to the President, December 3, 1912, in which he said:—

"So far as the government itself does not undertake the development of water power, it is necessary and desirable that we shall offer to those private interests which do undertake its development a sufficient opportunity for profit and a sufficient protection of their investment to secure the largest measure of development for which there is a present market, or for which a market can be profitably be developed."

WHAT THE ELECTRICAL ENGINEER CAN DO

What can the electrical engineer, or any member of the whole broad engineering profession, do to promote these principles? He can serve his own interest, that of his clients, be they private or governmental, and that of the country by insisting on the conservation of all the utility in water, under a comprehensive plan and can protest against the continuance of a wasteful, log-rolling, pork-barrel, petty larceny national policy of river improvement appropriations. He can see to it that the development of his own field shall be upon broad lines, and that power developments are not carried on without due regard for all the benefits that may accrue from complete stream utilization. If connected with a private company, he can favor a proper attitude on the part of his company toward the public, recognizing the latter's share in all public service business, and insisting upon publicity and support of sane regulation, to the end that State socialism may not replace the policy of development by intelligent self-interest. He may thus use his influence to cause the company to make of future necessity a present virtue. He can favor a progressive constructive policy, by giving his support as a citizen to the development of sound legislation by his State and the Nation, claiming weight for his opinion because of his peculiar technical training and knowledge. Finally, he can stand as a scientific, reasonable man between the professional demagague, on the one hand, and the capitalists honestly seeking investment, on the other; or between the unscrupulous corporation and the less well-informed public; so as to lend his influence to the determination of the truth and the working out of the problem on a basis of fairness, equity and progress.

ELECTRICAL CONTACT RESISTANCE

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WHEN an electric current is passed between two pieces of matter there is a loss of energy at the point of contact and a certain drop in potential results, which may be measured by a millivoltmeter. The voltage drop across such contacts, or indeed through the whole structure of the apparatus considered, is a common measure of the efficiency of the apparatus, the drop being ordinarily taken at the full-load current of the apparatus. To secure a more complete understanding of the subject the writer has at various times examined the effect on this potential drop, of current, pressure, materials composing the contacts, surface conditions of the contacts and area of the contacts. The effect of these factors is generally and correctly understood in a very general way, with the exception of the last one. That is, it is generally understood that the voltage drop across contacts can be reduced by decreasing the current, increasing the pressure between them, using a material of lower resistance, cleaning the surfaces, or increasing the area of the contacts themselves.

There can be no more fundamental and universally involved set of facts than those that surround the phenomena of the transference of current from one body to another. It is necessary in all apparatus to make such transference. and in the design of such apparatus to allow for the losses that always accompany such transference. Certain empirical formulae have been developed in the various branches of the profession for the valuation of these losses. They have a variable importance in different classes of apparatus, being of very little value in some and in others of very great value. In the design of switches, circuit breakers and the like this factor becomes of the greatest importance.

Current—It is generally understood that if in an electric circuit the current increases directly as the voltage, it may be assumed that we have to deal with a resistance, and it is also commonly assumed that this is true of contact resistances. If all the other variables are eliminated, it will be found that the voltage drop decreases directly as the current is decreased and vice versa. The writer has been at some pains to investigate this point at various times, and has satisfied himself that the following may be expressed as the first law of contacts:—

I—All other conditions being constant, the voltage across a contact joint will increase directly with the current; or, the joint between two materials behaves exactly like a resistance.

Pressure—It is generally appreciated that it is very desirable to hold the contacts in as firm engagement as possible for the purpose of reducing the apparent resistance between them. At very low pressures the effect of dirt and oxide has an undue influence, and at very high pressures the contacts themselves have a tendency to distort and alter the conditions of contact. Many tests have been incorrectly interpreted, due to errors from these sources. The writer has investigated this condition with direct currents as high as 12 000 amperes, and pressures as high as 8 000 pounds, and has always found erratic results at both high and low pressures, due to the causes mentioned. The most satisfactory device for investigating the influence of pressure on the voltage drop across contacts was the air pressure device shown in Fig. 1. This consisted of a pair of heavy bus-bars fed by unipolar generators having a capacity of something over 10 000 amperes at a voltage of about three volts. To these bars were fastened a pair of long and somewhat flexible bus-bars, which extended out and carried on their outer ends two anvils, between which the contacts to be tested could be placed. Pressure was applied by a big air cylinder pushing against a solidly anchored I-beam. The bus-bars were sufficiently flexible to allow nearly all of the pressure to be taken by the contacts, the pressure needed to bring them together being only a fraction of one percent of the final pressure obtained, which was in the neighborhood of 8 000 pounds at normal air pressure, and could be raised by increasing the compressor pressure.

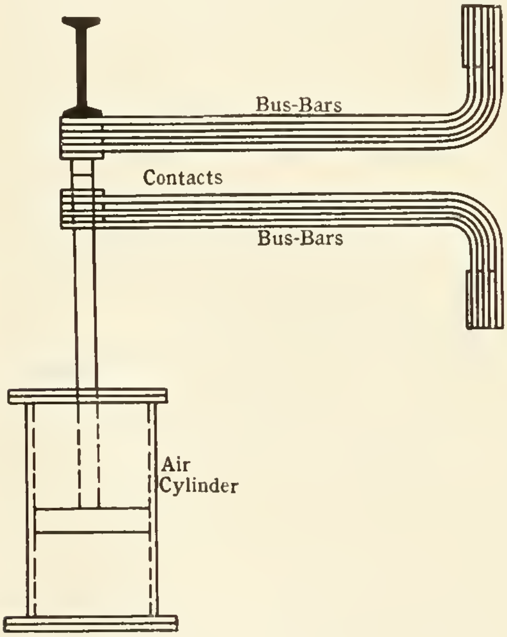

FIG. 1—DEVICE FOR TESTING ELECTRICAL CONTACTS

The pressure could be varied quickly by admitting or releasing air from the cylinder, the pressure on the contacts being read directly by a suitably calibrated gauge, subject only to a slight correction for friction. The results of over five thousand observations on this machine lead to but one conclusion, which may be called the second law of contacts:—

II—Where the conditions of the surface in contact are not affected thereby, the voltage across a contact will very inversely with the pressure.

This law has been tried out by the writer in other apparatus, and may be depended on within wide limits, which are indicated by the law itself. So long as the pressure is not low enough for a little dirt or oxide to have a limiting effect or high enough to distort the contacts and thus change their contact conditions, the law will hold.

Contact Materials—The writer has made some rather extensive experiments with various materials as contacts, but the question was approached from another viewpoint than that of contact resistance. In general, the resistance to arcing and permanence of surface are the limiting factors. Enough data was obtained to give as a third law of contact:—

III—The resistance between materials depends directly on the internal resistance of the materials, those having a low resistance having also a low contact resistance.

This point was not quantitatively considered in the great majority of the investigations, due to the fact that it is of more or less minor importance in the design of practical switching devices, the designer being limited therein by certain other considerations, such as those given above. From the data at hand it would seem that under the same surface conditions brass has from four to eight times the resistance of copper across the contacts, aluminum about 30 and carbon about 300 to 400 times. These values have not been carefully checked and should be accepted only as roughly comparative.

Condition of Contact Surfaces—In the investigation mentioned the condition of the contact surface was a constant source of variation, and an attempt was made, therefore, to determine just what effect dirt and oxide would have on the resistance. This was determined, but cannot be defined, due to the fact that there are no measurable degrees of dirtiness. It was finally decided to eliminate this variable by cleaning the contacts at each test, and this was done, and the laws defined above are based on experiments made with cleaned contacts. No direct law can be deduced from this other than that foreign matter increases the resistance between contacts, and this is an axiom rather than a law.

Area of Contacts—The three laws stated above were deduced from experiments that had for their prime object the determination of the proper size, or rather area, of contact required for a given voltage drop and current. This is the commonest requirement that the designer has to meet, and the answer to this question is of the first importance. A little survey of what has been done in the field of determining the area of such contacts may be of value. The first fixed point is the old one of the knife switch with a split jaw into which a blade was forced. The current passed from this blade to the jaw, through a rectangular surface, and it is common practice to limit the current in such jaws to fifty or seventy-five amperes per square inch. In the construction of one of the early types of carbon circuit breakers, the current between the brush face, and the stationary contact was limited to two hundred amperes per square inch. In certain very successful circuit breakers of the same kind, more recently designed, this value is increased to over five hundred amperes per square inch. This is a very wide variation in practice, and it looked as if such empirical rules might be improved upon. A series of very careful tests were made on various square contacts with surfaces varying from one to nine square inches. There resulted no definite rule. Certainly there were no such differences as nine to one, as the areas would indicate there should be. That there was some difference cannot be denied, but this was only slightly in favor of the large contacts. It seems reasonable to give as the fourth law of contacts the following:—

IV—The resistance between contacts depends not upon their area, but only on the total pressure with which they are forced together.

This law is new and will meet with some criticism. A little consideration will show that it follows directly from the second law given above. Consider a contact having a certain current passing through it and a certain resistance. A certain drop in potential will result. Suppose now that this contact be paralleled with another contact, the exact duplicate of the first one, dividing the current and pressure between them evenly. Having one-half the pressure, the contacts will each have twice the resistance by *Law II*, and, having at the same time one-half the current, they will have each exactly the same drop as the single contact previously used. If they are combined and considered as one contact, the current and the drop across both combinations will be the same, and consequently the equivalent resistance will be exactly the same. But the area of contact and the area in contact will be twice as great with the two contacts as with the single one. We have then by such a substitution doubled the area in contact without changing the resistance. *Law IV* and *Law II* must, therefore, either stand or fall together, being simply the same law stated in a little different form. The fact that they were discovered and formulated independently

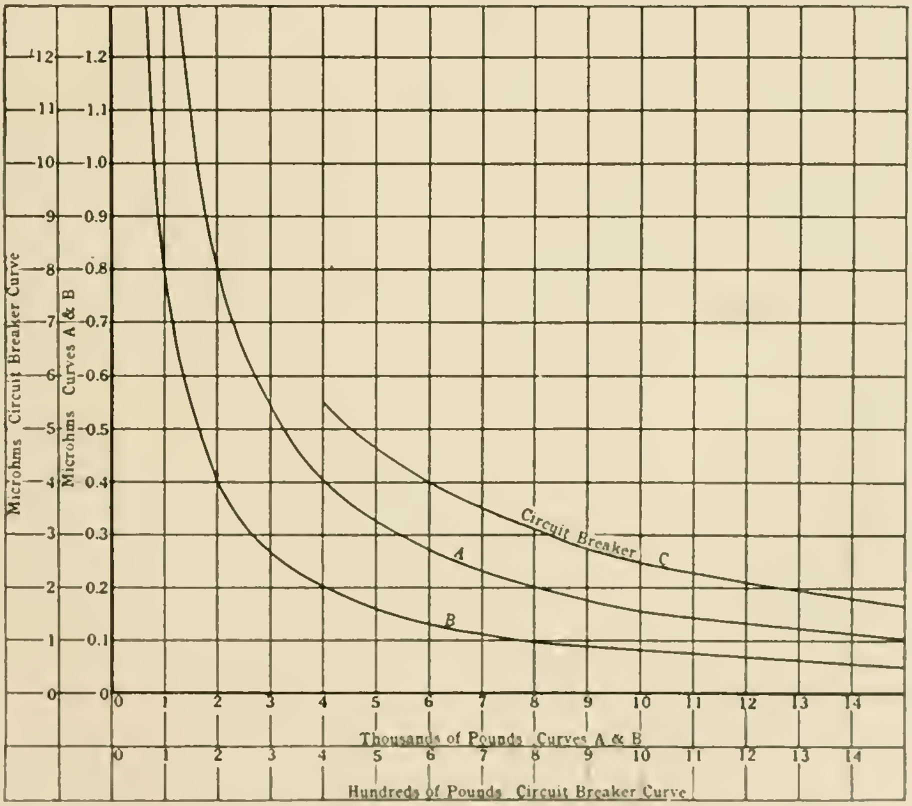

FIG. 2—CURVES OF RESISTANCE AT VARIOUS PRESSURES

by the writer before their practical identity was discovered, seems to indicate that they will stand. These laws undoubtedly will upset certain preconceived notions and standard practices, and before they will be accepted by practical men the apparent discrepancy between such standard practice and the laws will, in a measure, have to be accounted for. Before doing this it will be desirable to give some results of tests and put the whole matter on a little more quantitative footing.

As has been mentioned above, there is a considerable variation in resistance even on cleaned contacts, due to the variable amount of dirt and oxide present. It is, therefore, impossible to give an exact value to contact resistance in terms of pressure. It is possible to give the limits between which the values will fall for cleaned copper contacts, as shown in curves *A* and *B* in Fig. 2. The values are plotted in thousands of pounds and microhms, but the same curves hold if the pressures are divided by ten and the resistances multiplied by ten. That is, for lower pressures we can consider the pressures as given in hundreds of pounds and the resistance values as ten times greater than those given in the curve.

These curves express the formulaa, $P \times R = 0.0008$ and $P \times R = 0.0016$, P being pressure in pounds and R, resistance in ohms, these being the limit values for cleaned copper contacts. These expressions are very accurate between the limits of 1 500 pounds and 8 000 pounds, but at pressure below the lower value there are likely to be some very erratic values. This is due to the fact that at the lower pressures the influence of dirt and oxide is very much more likely to interfere with the contacts than at the higher pressures. A careful examination of a considerable number of tests at the lower pressures seems to fully confirm the laws for the whole range of pressures.

The fact that the resistance is independent of the area in contact seems at first sight to be at variance with certain information and standard practice that has grown up over a long period of time. The average man is a little confused by the fact that, with the same voltage drop, big contacts operate at lower temperatures than small ones, due to the increased linear dimensions and surface, and therefore the heat radiating qualities.

The excellent performance of the so-called carbon circuit breaker and similar devices having laminated contacts, seems to prove that the area is an important factor, for it is on the excellent surface conditions under the flexible brush of that type of apparatus that the good behavior apparently rests. This is probably a mistake. A test of such a brush under definite pressure conditions disclosed that the pressure-resistance curve followed the same laws that the solid contacts did. This test was not made for the purpose of checking this point, however, but to get comparative results between different forms of brush. The contact surfaces were not cleaned and the values obtained were greater than would have resulted from a solid contact following curve *A*. The actual values are given as the circuit breaker curve *C* in Fig. 2. This curve is made to the lower scale of hundreds of pounds, and the values are given in microhms in the place of tenths of microhms as with the curves *A* and *B*. This higher value is to be expected from the condition of the contacts. Had they been as carefully cleaned as those in the tests that led to curves *A* and *B*, curve *C* would undoubtedly have fallen within the limits set by those curves.

The explanation of the apparent efficiency of the laminated brush lies in the following points: First, the laminated brush is an excellent contact cleaner, the narrow leaves scraping the dirt away and there being a good space between the leaves for the dirt to be pushed away. The total pressure is, therefore, taken on the contacts. With a solid brush, a little piece of dirt may take a large portion of the pressure, leaving a considerably less actual pressure on contact surfaces. Where surfaces can be kept clean the solid brush has been very successful, as for example in oil switches; second, the laminations serve to make the rate of oxidation much slower by forming a close contact and excluding the air; third, the laminated brush, being elastic, tends to apply the pressure much better than a rigid mechanism. Wear in the mechanism is thereby compensated for and the result is a better maintenance of contact conditions over a long period of time. It is common practice to grind in switch jaws, and such grinding commonly results in a lower voltage drop across the switch. This is not due, however, to more surface being in contact, but only to the surface that is in contact being cleaner. The very great success of contacts such as those on the pneumatically-operated switches on street cars which have very high pressures and only a line contact of negligible area, supports the conclusions that have been drawn above.

It is probable that laminated brushes will hold their own for the particular service, in which they are now used. That is, in places where they are infrequently opened and, therefore, not likely to be exposed to excessive oxidization. In such a location they seem to be superior to the solid contacts, but where contacts are opening often, as on motor-starting devices and the like, which operate once an hour or oftener, it is very doubtful if they are as good as a solid contact, provided the solid contact is spring driven, so that the pressure is maintained constant. With this theory in mind, it is easy to understand the excellent behavior of the so-called butt contact, now coming into general use on small capacity oil circuit breakers and destined to come into use on large ones. Here we have two plain surfaces, pressed together by a spring that allows considerable wear before the pressure between these surfaces falls off appreciably. The arcing takes place between these surfaces and in a very short time they start to wear away roughly, the contact often being a mere pin point. Many thousands of such contacts are in successful use, their simplicity and cheapness of manufacture and renewal being important points in their favor. They have met with considerable opposition not only from operating men who did not believe that they would function properly, but from designers of such devices who were ignorant of the principles of contacts, and relied solely on theory that was based on false conceptions of the governing conditions.

On reviewing the investigations that have been summarized here, and considering a number of parallel investigations, the one fact that seems most striking is the very evidently traditional nature of some of the data with which the engineers of today are working. There exists in scattered form abundant data to prove the laws of contacts as stated above, quite independent of the work here outlined, and it is probable that there are men who appreciate them quite as well as the writer. They have never been formulated, so far as the writer is aware, and certainly there are many designers who are not only ignorant of them, but who are absolutely wrong in their notions on this very important point. The expense of examining many similar points is relatively small, and it is to be hoped that the engineering profession will maintain a healthy scepticism as to facts that rest largely or wholly on tradition.

PROPERTIES AND USES OF BAKELITE MICARTA

R. W. E. MOORE

MICARTA is a new and remarkable material developed primarily for insulating purposes; but on account of its superior mechanical properties it has found its way into many other applications. It is produced in several grades, depending largely on the kind of raw materials entering into its manufacture. The main difference between the two principal grades is their relative resistances to temperature. The first grade is suitable for temperatures not to exceed 80° C. where the bonding material begins to soften slightly. The second grade utilizes the new synthetic resin known as bakelite as the bonding material, and will withstand temperatures well above the boiling point of water without deterioration. Micarta is made into tubes, from 3/16 inch inside diameter and 3/64 inch wall, up to tubes of 45 inches inside diamter and almost any thickness of wall. It is also made into tubing of rectangular, hexagonal and other shapes, and plates in any size up to 36 inches square and 1.5 inches thick. All of these shapes are made very accurately to dimensions as the material machines, drills and finishes very well. It may be cut into many peculiar designs, a few of which are shown in Fig. 1. Any of the finishes that are usually desired for this class of material may be applied to bakelite-micarta.

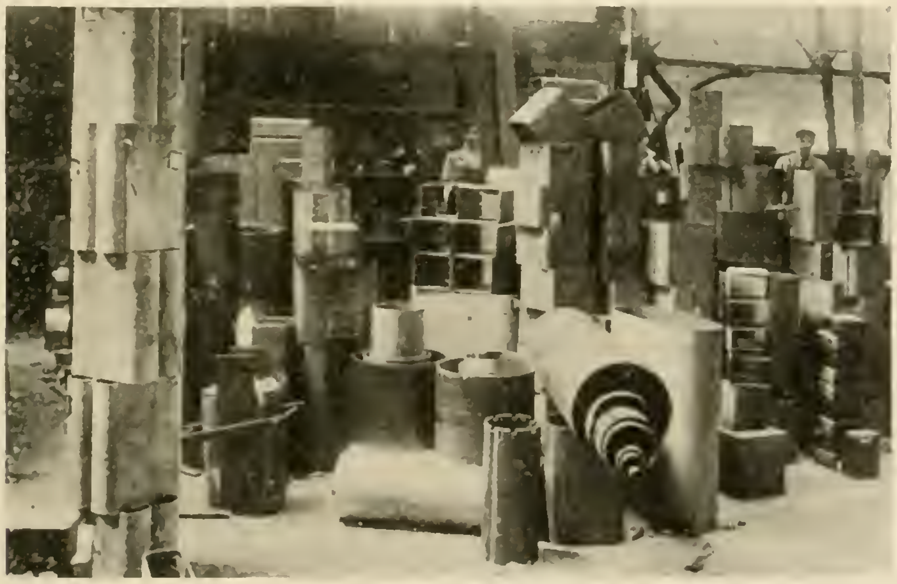

FIG. 1—A COLLECTION OF BAKELITE MICARTA PRODUCTS

Showing variety of shapes into which this material is manufactured.

It may be varnished with bakelite varnish, linseed oil varnish, or asphaltum varnish. When polished by ordinary buffing methods it takes a high finish and has a dark brown color. It is also manufactured black and it then has the appearance of hard rubber.

CHARACTERISTICS

Thermal—Severe tests have been applied to bakelite-micarta to determine its heat resisting properties, and it has been found to withstand a temperature of 125 degrees, C. continuously without deterioration and will withstand a temperature of 150 degrees, C. for short periods of time. It is infusible, that is, will not soften at any temperature, but will be destroyed when the carbonizing temperature is reached. If sufficiently heated and brought in contact with a flame, it will burn, but with difficulty. For this reason, and on account of its density it withstands an electric arc better than other organic substances such as hard rubber, or moulded insulation and builtup mica which contain natural resins which are not dependable in their fusing and distilling properties. The heat conductivity of this material compares very favorably with most other insulating materials, and it is a better heat conductor than fibre. Its expansion is 0.00002 inch per degree, C. (silver is 0.0000192 and glass 0.000025).

TABLE I—BREAKDOWN VOLTAGES

Test	Plates		Tubes	
	1/16 in. Thick	¼ in. Thick	1/16 in. Thick	¼ in. Thick
No. 1	65 000	115 000	51 000	103 000
" 2	62 500	125 000	57 500	90 000
" 3	72 500	129 000	50 000	90 000
" 4	76 000	139 000	52 500	98 000
" 5	77 500	132 000	50 000	104 000
Average	70 100	128 000	52 500	97 000

Electrical—The dielectric strength of bakelite-micarta is high compared with other materials of this class, being about 500 to 1 000 volts per mil of thickness up to one-quarter inch. Its dielectric strength at various thicknesses, together with average values is given in Table I. It has a specific inductive capacity of about 5.2 and a power-factor of 0.024 at 180 cycles (clear mica has a specific inductive capacity of 5.5 to 6 and a power-factor of .001). The insulation resistance was taken on samples after they were exposed to atmospheric conditions for 48 hours (20 degrees, C. and 60 percent humidity), and found to be 2.13×10^{13} ohms per cubic centimeter at 625 volts per centimeter thickness (the insulation resistance of mica is about 8.75×10^{15} ohms per cubic centimeter).

Chemical—Bakelite-micarta is insoluble in all the ordinary volatile solvents, such as alcohol, turpentine, benzine, chloroform, benzol, etc. It is also insoluble in weak solutions of acids and alkalies, but strong solutions attack it. It is remarkably non-hygroscopic, increasing in weight only a little over one percent when immersed for 24 hours in water. It is insoluble and entirely unaffected by transformer, lubricating or other oils. It is unaffected by ozone, which gives it an advantage for electrical purposes over hard rubber, natural resinous substances, etc.

TABLE II

	Bending Test		Compression Test		
	Ult. Stress	Per sq. in.	Ult. Stress	Per sq. in.	
Tension Test Ult. Stress per sq. in.	Cut across sheet	Cut along sheet	3/8" x 5/8" tubes, 2" long, set on end	Blocks of ½" broad, 2" long, 1" high, set on edge	Averge* Brinnell hardness
			Bakelite-Micarta		
18750	26200	18350	17125	19900	40.4
21060	26150	18750	17373	21700	
Av. 19905	26175	18550	17250	20800	
			Fibre		
14960	21150	14450	16475	11300	
14740	21800	14550	15450	10825	
Av. 14850	21475	14500	15960	11050	

Physical—The tensile, compressive and bending strength and hardness of bakelite-micarta as compared with white fibre is given in Table II. It has a specific gravity of about 1.25.

One of the prime requisites of any good insulating material is homogeneity of structure. Its absence is one of the very serious drawbacks in many of the insulating materials used at present, because of the fact that internal mechanical stresses are very likely to develop, causing cracking or distortion, and requiring a comparatively large factor of safety. Bakelite-micarta, however, is remarkably dependable in this respect. Its almost perfect homogeneity is well brought out in the accidental fracture of the six-inch tube shown in Fig. 2. This tube broke whlie a mandrel was being withdrawn, and was under a tensile stress due to shrinkage and also a compressive force applied at the end of the tube in pressing it off the mandrel. The uniformity of the fracture wave shows the homogeneity of the material. A harmonic analysis has been made of this wave, Fig. 3, and it is seen that the break is largely of one frequency with small sympathetic wave components of slightly lower and higher frequencies. Table III gives the complete list of the waves and their phase angles, which make up this wave fracture.

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*Degree of hardness by this method is determined from the width of the depression made in the material by a standard ball under a standard pressure.

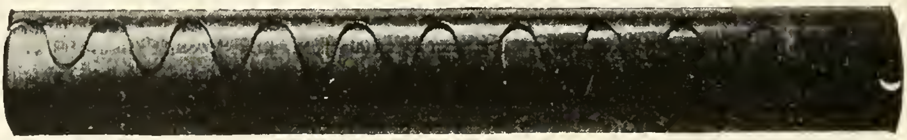

FIG. 2—ACCIDENTAL FRACTURE OF A SIX-INCH MICARTA TUBE
This took the form of a sine wave, thus indicating remarkable homogeneity.

APPLICATIONS

Among the applications of bakelite-micarta are brushholder tubes and collector insulation. Here insulating material is required which will retain its dimensions accurately when subjected to variations of temperature and moisture. It is excellent for tubes over condenser terminals, such as shown in Fig. 4, which are filled with cement in a melted state, for here the tubes must keep their shape while the cement at rather high temperature is being poured, and also they must withstand the baking while the black enamel is being applied as a finish. It is especially good for tank linings for oil immersed apparatus on account of its being impervious to moisture, as it will not carry moisture into oil, nor

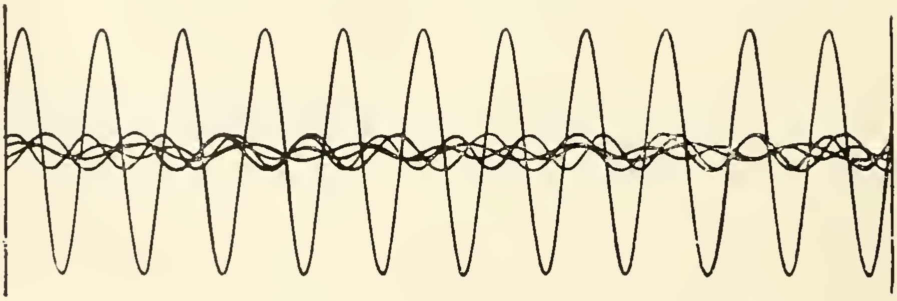

FIG. 3—HARMONIC ANALYSIS OF FRACTURE WAVE SHOWN IN FIG. 2

is it affected by the oil. It has been applied in this way in electrolytic lightning arresters, where there would be danger of the electrolyte getting into the oil and being absorbed by the lining. Its acting as an insulating barrier here makes possible a great reduction of the insulating distance to the case. A sleeve or conduit for the high tension leads for automobile motor ignition is shown in Fig. 5. Induction coil cases are also made from bakelite-micarta. Here it meets the high temperature demands very nicely. It has been used for intricately machined end plates on wireless telegraph generators, because they were to be operated along the coast where there would be considerable moisture and because the speed of operation required high mechanical strength. The material works very nicely into noiseless gear wheels, and is used for this purpose as timing gears for automobile ignition work. It fills a long-felt need for a material for making spools and tubes on which coils can be wound and then impregnated in molten gums, because precautions are not required to keep these spools and tubes from collapsing under the heat during impregnation; also for coils treat-

TABLE III

Wave	Amplitude	Phase Angle
1	.021	45. lag
2	.023	71.6 lead
3	.046	9.5 lead
4	.018	18.4 lag
5	.028	31.4 lag
6	.014	18.8 lag
7	.014	8.6 lag
8	.086	4.0 lead
9	.029	10.0 lead
10	.214	6.0 lag
11	1.500	1.8 lead
12	.209	4.8 lead
13	.066	9.4 lead
14	.036	17.1 lag

FIG. 4—HEAVY CONDENSER TERMINAL WITH MICARTA BUSHING

FIG. 5—CONDUIT FOR USE OVER AUTOMOBILE ENGINE FOR CARRYING HIGH TENSION LEADS

ed with varnishes which have to be baked at a high temperature.

Another application is commutator bushings and V-rings. Bakelite-micarta has the mechanical strength needed here and stands up well under the baking treatments necessary for the final seasoning of the commutator. While there are many other interesting applications, these may serve to give an idea of the broad fields to which this material may be applied.

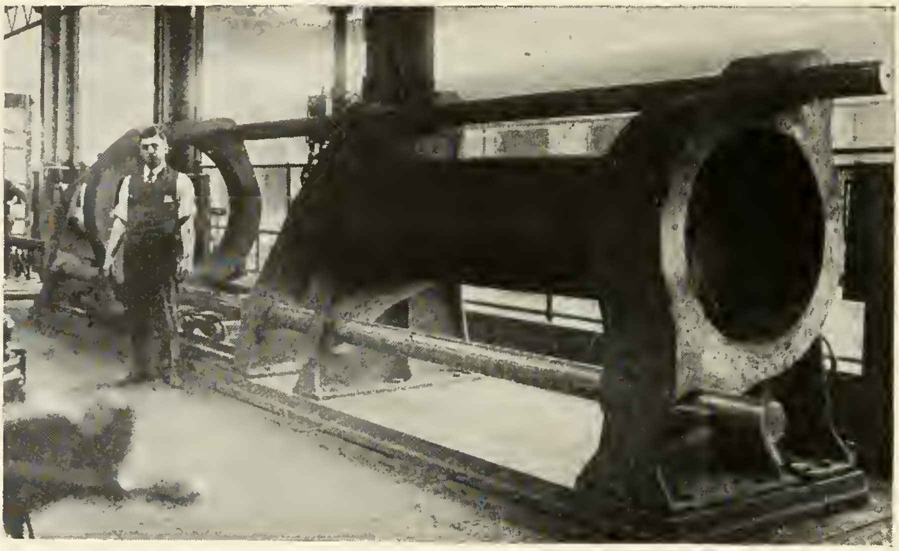

FIG. 6—LARGE PISTON TYPE PRESS FOR REMOVING MANDRELS UPON WHICH MICARTA TUBES ARE BUILT

From the foregoing it will be seen that bakelite-micarta meets many insulating requirements more satisfactorily than the best materials which have been used in the past, and that it is suitable for much more severe service than any other insulating material has yet been able to meet.

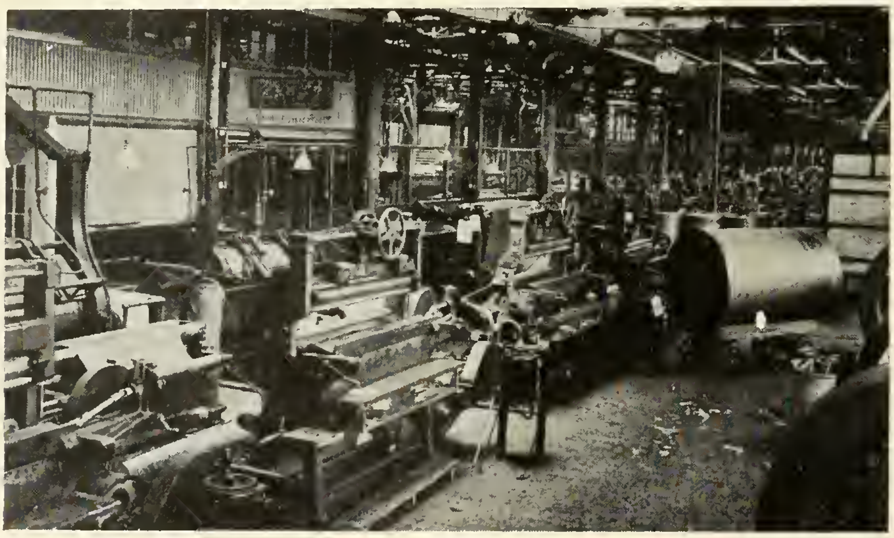

FIG. 7—A FACTORY DEPARTMENT DEVOTED EXCLUSIVELY TO THE MANUFACTURE OF BAKELITE-MICARTA

A STUDY OF INSULATION PROBLEMS*

C. FORTESCUE

The object of this article is to emphasize a principle of electrostatic theory by which the individual units of a system of conductors may be arranged to protect one another.

ONE aspect of the insulation problem that has received but little consideration is the proper grouping of conductors, so that they shall assist in insulating one another. As an example, consider two spheres 25 cm. in diameter and 25 cm. apart, at potentials + 200 000 and — 200 000 and a small thin disk of conducting material connected to ground and placed near the spheres. The disk may be placed in a number of positions in which it is insulated from both of the spheres, but there is only one set of positions in which it will cause no disturbance of the electric field, namely, those lying in the zero potential surface or plane of symmetry midway between the two spheres. If one of the spheres be removed, the balance will be disturbed and the remaining sphere will discharge to the disk. Thus the presence of the sphere of potential + 200 000 has served to insulate the sphere of potential — 200 000 from the grounded disk. Very thin wires may be brought into the field of the two spheres and maintained at a difference of potential many times larger than their normal disruptive voltage.

In such cases as these the ordinary rules of procedure followed in insulation methods are seemingly violated. Thus sharp edges and fine wires are more effectively insulated than thick rounded edges and large wires. In practical work, conductors usually have edges where the intensity becomes high, and therefore, if by some method, these sharp edges can be insulated as effectively as large rounded edges, a valuable advantage will have been gained

A PRINCIPLE OF ELECTROSTATIC THEORY

If a region in any particular electric field be isolated or cut out by any number of closed surfaces, then the electric field in this region will remain unchanged, whatever change may take place in the external electric field, if the potentials at all points on the enclosing surfaces are maintained at their original values. It follows that the intensity due to the surface distribution will, at each point of the region, be the same as that of the assumed electric field. The potential in such a region will be unaffected by any change in position or electrification of external bodies, since it is uniquely determined by the surface potential distribution which remains unchanged. It is also obvious from this principle that two or more regions, completely separated from one another by any number of surfaces, may each have a different electric field, if at every point of the dividing surface or surfaces between any two of the regions, the fields in these regions have the same potential.

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*Revised from a paper read before the American Institute of Electrical Engineers.

The truth of the principle just stated is almost self-evident, for it is known that when the potentials of a system of conductors are given, there is only one possible solution of the electric field consistent with the proper conditions. If, therefore, a solution be known that will give the same potential at each point of the bounding surfaces of a given region as the assigned potentials, then this must be the only possible solution. It is not so easy to see that the field within the region is independent of any external influences. This may be deduced from the fact that, in order to produce a potential within the region, an external system must also produce a potential at each point of the surfaces, and, since the potentials at the surfaces are maintained constant, the effect of external bodies within the region must be zero. Changes in the external electric field have the effect, however, of altering the charges at each point of the surface. In other words, the effect of any change in the external system is to produce a change in the capacity of the system of charged bodies at the surfaces of the region, in such a way that there is a change in the surface charges, the potentials remaining constant, of such a nature as to completely annul the effect within the region of the change in the external system.

A few simple illustrations of electric fields produced in accordance with this principle may serve to give a more vivid conception of its use.*

Consider two parallel plane conductors, forming two portions of the surface of a solid dielectric. To produce within the body a uniform field corresponding to that between two infinite parallel planes having the same potentials as the two conductors, all that is necessary is to produce at each point of the surface of the dielectric a potential equal to that of the uniform field at that point. The whole surface of the dielectric might be considered as mapped out in equi-potential contour lines infinitely close together and each line may be imagined to become a conductor which will be supposed to be connected to an external source of the proper potential.

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*The analytic theorem upon which this principle is based may be found in Maxwell's "Electricity and Magnetism," 1904 edition, p. 136. A more general proof of the same theorem is given in Kelvin and Tait "Treatise on Natural Philosophy," 1903 edition, Vol. 1, Chap. 1, Appendix A (c). A full discussion of Green's problem, which has some bearing on the above principle, may be found in Vol. 2 of the same work, Articles 499 to 508, inclusive. Reference may also be made to Jean's "Electricity and Magnetism," Articles 186, 187 and 1888, and to Webster's "The Theory of Electricity and Magnetism," the last paragraph of Article 86.

A dielectric sphere in a uniform field furnishes an interesting application of this principle. A section of the equipotential surfaces of the electric field in the neighborhood of a dielectric sphere in a uniform field, with and without the proper potential distribution, is shown in Figs. 1 and 2.

Cylindrical conducting bodies and insulating structures are of common occurrence in practical problems. Suppose it be required to insulate a *short* external cylinder from a *long* internal concentric cylinder. Lines may be drawn from the ends of the external cylinder to the nearest points on the ends of the inner cylinder, see Fig. 3. The surfaces of revolution formed by these two lines and the two cylinders may be taken as bounding surfaces of the enclosed region, which will be assumed to have within it a potential

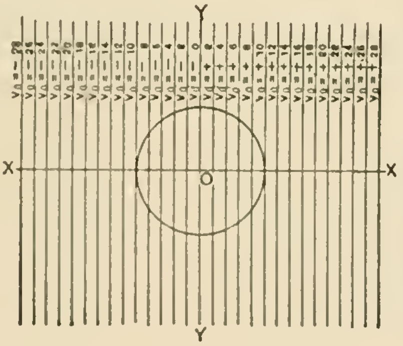


FIG. 1

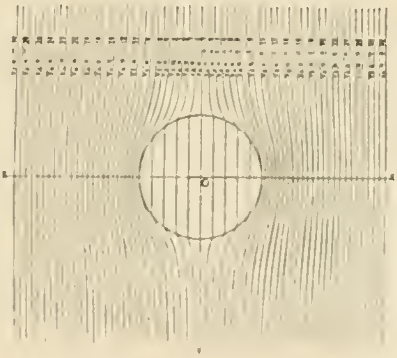


FIG. 2

$$V_1 = B \log_e r + A$$

where r is the distance of the point, whose potential is V_1 from the axis of the cylinders and B and A are constants determined from the potentials of the two cylinders. The equipotential surfaces of the field will intersect the surfaces of revolution formed by the two lines in circles, the planes of which will be perpendicular to the axis of the cylinder. If each circle were a conductor connected to an outside source having the same potential as that of the equipotential surface on which the circle lies, the distribution over the surface so produced would cause the potential within the enclosed region to be equal to

$$V_1 = B \log_e r + A$$

If, instead of the external cylinder, a disk be substituted of infinite radius with a hole in it of the same diameter as the cylinder, and with its plane at right angles to the axis of the cylinders, and if the internal cylinder be provided with a similar disk at each end; taking z as measured from the point of intersection of the axis of the cylinder and the plane of the middle disk, a field may be assumed between the middle and upper disks, having its equipotential surfaces parallel to the disk, and the potential of the field will be

$$V_0 = C + D\,z$$

C and D being determined by the potentials of the middle and outer disks.

The region between the inner cylinder and middle disk may be assumed to have an electrostatic field, the equipotential surfaces of which are cylinders concentric with the inner cylinder, and whose values are given by

$$V_1 = B \log_e r + A$$

The surface of separation between the two regions having potentials V_1 and V_0 will have for its equation,

$$r = e^{\frac{C-A+Dz}{B}}$$

$$= a\left(\frac{b}{a}\right)^{\frac{2z}{l}}$$

where

$a = e^{\frac{C-A}{B}}$ = radius of hole in outer disk.

b = radius of inner cylinder.

l = length of inner cylinder.

If the three disks are limited in diameter, the middle one being less than the other two, and if the region between the two outer disks is completely enclosed by an external cylinder extending from one to the other, the outer edge of the middle disk may be insulated from the external cylinder in a similar manner. These three examples are illustrated in Figs. 3, 4 and 5 respectively.

LIMITATIONS IN PRACTICAL APPLICATION

In practical applications of this principle, the means for producing a potential distribution over a surface are limited. A finite number of steps must be used and the potentials must be applied to strips of metal of finite widths in such a way that the intervening surface between two adjacent strips shall have the proper potential at each point. However, with proper care in laying out the various parts, a fairly close approximation may be made to ideal conditions.

The application that at once suggests itself as being most suitable, is the insulation of high-voltage transformers, particularly such as are used for testing purposes. Application to line insulators will also be taken up and miscellaneous uses to which the principle may be adapted.

CORE TYPE TRANSFORMERS

Before considering the application of the principle to the insulation of transformers, it will be well to consider the mechanical characteristics of the materials available for insulating transformers. Moulded material, on account of the large bulk required in high-voltage transformers, is probably out of the question. At present, the most suitable materials are obtainable in the form of cylinders and plates. The insulation of high-voltage transformers will therefore consist of structures of concentric cylinders and parallel plates of solid insulation interspersed with oil. The forms of electric field that are most suitable with such insulation structures, namely, the uniform field and the field of logarithmic potential, give also the best conditions of stress in the materials and are adapted to the natural form of the winding and core structure of transformers.

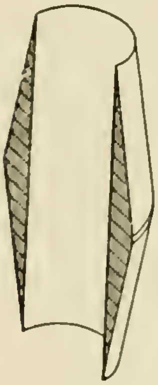


FIG. 3

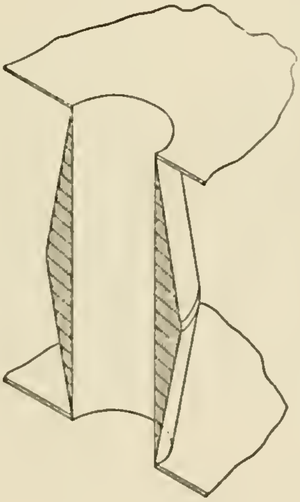


FIG. 4

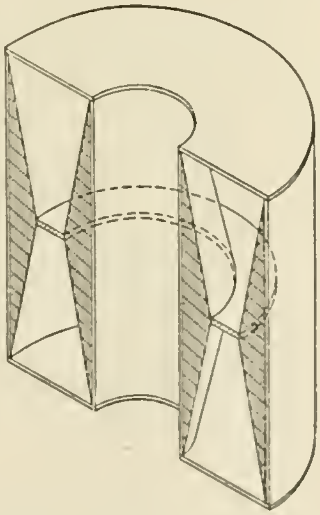


FIG. 5

The simplest form of high-voltage transformer has one terminal conected to ground through the core and case and the other is brought out through a high potential bushing in the cover. Fig. 6 shows the diagram of connections for such a transformer designed in accordance with this principle. The high-tension winding of this transformer is made up of a number of discoidal-shaped coils, arranged and connected so that the potentials of the coils progressively decrease from the center coils outward. Thus, the coil marked, "terminal coil" has the highest potential, while that marked "ground coil" has the lowest potential. Each coil is so placed that it lies on the equipotential surface, corresponding to its potential, of an assumed uniform field in the region included between the middle high-potential coils and the outer or low potential coils. The whole high tension winding thus assists in producing in the external region in close proximity to the windings, and in the part of the internal regions which are unoccupied by the cylindrical barriers, what substantially amounts to a uniform electric field.

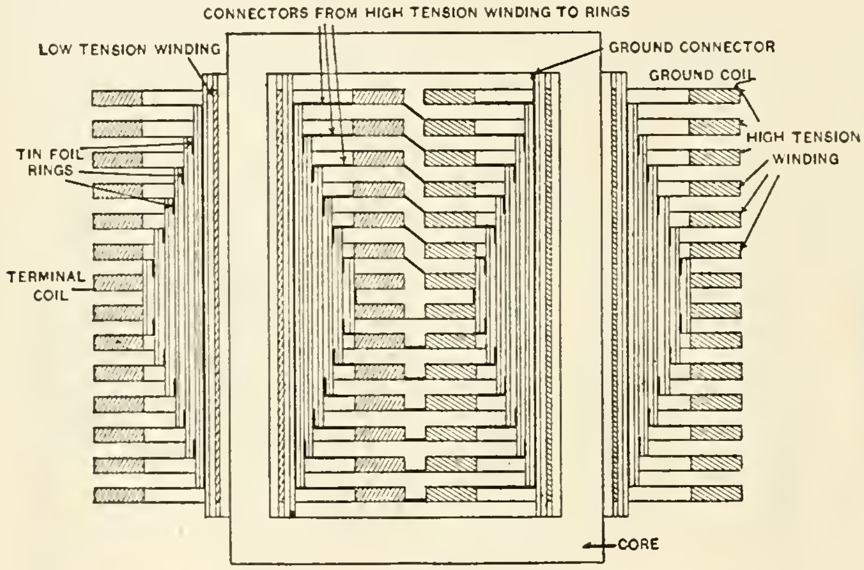


Fig. 6—Insulation Scheme for Transformer Designed to Operate with One End Grounded

The external surface of the cylindrical insulating structure which serves to insulate the core and low-tension winding from the high-tension winding is shaped according to the internal field of logarithmic potential and the external uniform field, as shown in Figs. 4 and 5. The potential distribution over the surface of this cylindrical structure is produced by connecting unclosed rings of tin foil on the insulating cylinders to the proper point of the high-tension winding. The top and bottom rings on each cylinder are connected together by a thin strip of copper, which also serves to connect an upper to a lower coil. Thus the ring and its connecting strip lie on the proper equipotential surface of the system, and therefore produce no disturbance in the electric field. Moreover, the ring on account of its width, helps to produce the proper potential at each point of the surface of the cylindrical barrier lying between it and the adjacent ring.

The outlet bushing also is designed so that when in position the end of each conducting layer will lie on the equipotential surface of the system having the same potential, thereby producing the minimum disturbance. This outlet bushing is not shown in Fig. 6. A transformer built according to this scheme is shown in Fig. 7, partly assembled. Fig. 8 shows the same transformer with coils and iron assembled, but without external barrier.

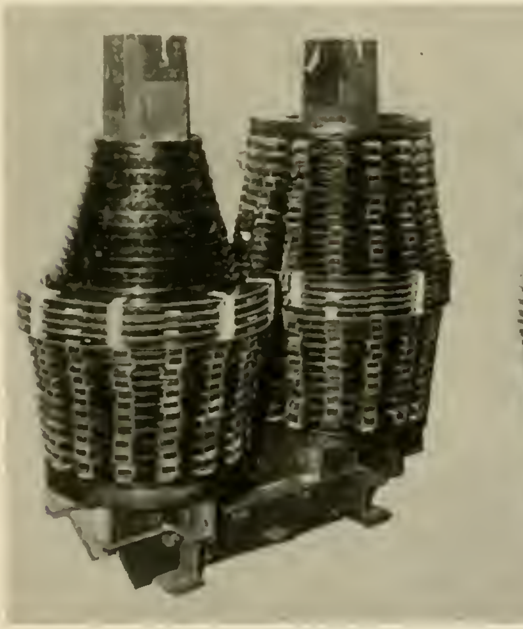


FIG. 7—HIGH VOLTAGE TRANSFORMER PARTLY ASSEMBLED

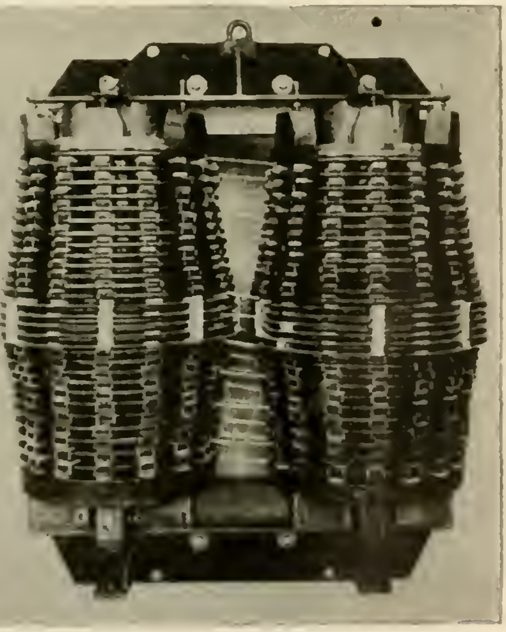


FIG. 8—HIGH VOLTAGE TRANSFORMER WITH EXTERNAL BARRIER REMOVED

Fig. 9 shows the transformer with external barrier partially assembled, and Fig. 10 shows the transformer complete in tank. No attempt was made to produce an artificial distribution of potential over the surface of the external barrier of this transformer which was made of fullerboard, on account of the impossibility of obtaining true cylindrical surfaces with such material. After this transformer was completed, it withstood successfully the tests given in Table I, applied in succession. The potentials indicated by needle point spark gap were 35 percent higher than given by ratio. At a later date, the transformer was excited so as to give by ratio a potential of 623 000 volts effective above ground without the terminal in place.

The form of transformer next in degree of simplicity is designed to operate with the middle point of its high tension winding grounded. Instead of one transformer designed to operate in this manner being used, two transformers, like that already described, may be used, and while it is somewhat more costly to make two such transformers, there are advantages in having two units that can be used for testing independently. When two transformers are used in this way, the difference of potential obtainable with the same conditions of insulation stress is double that of one. Thus two transformers, each capable of producing 500,000 volts to ground, when so combined will be equivalent to

TABLE I

High Tension Potential Above Ground By Ratio	Time of Application
400 000 volts	1 minute
450 000 "	0.5 "
500 000 "	1 "
525 000 "	1 "
573 000 "	10 seconds

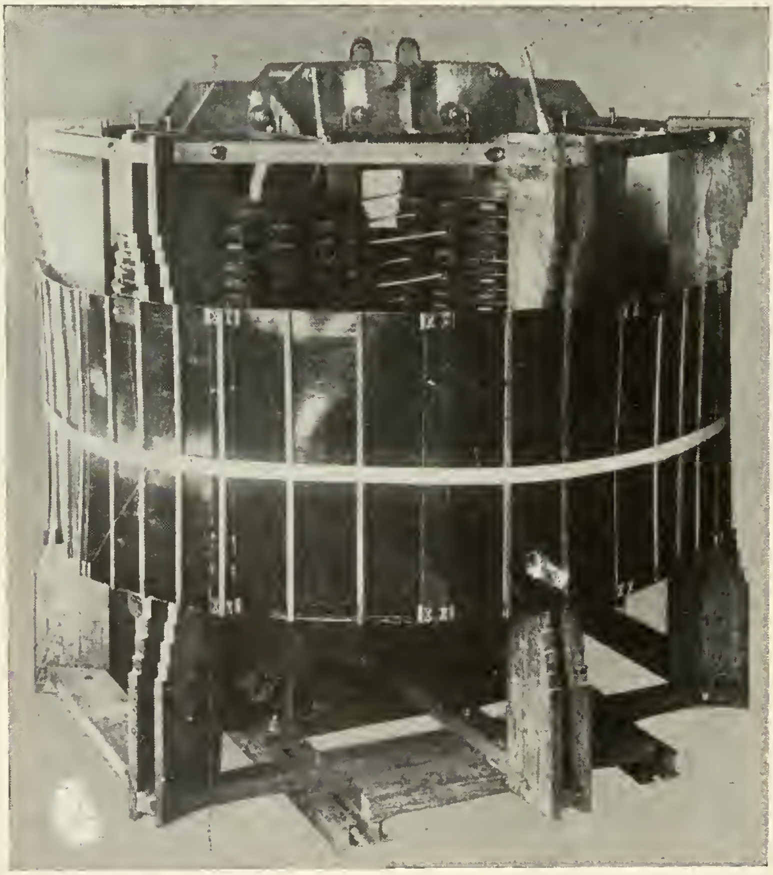


FIG. 9—HIGH VOLTAGE TRANSFORMER WITH EXTERNAL BARRIER PARTLY ASSEMBLED

a one million volt transformer with the middle point grounded. The design of a transformer to operate with the middle point grounded may be made according to the scheme shown in Fig. 11.

A transformer is sometimes required capable of operating with either end of the high tension winding grounded. A design for such a transformer may be made according to the scheme shown in Fig. 12. The insulating structure between the groups of coils on different phases may be made up of flat sheets, in which case the surface potential may be such as to give a uniform field. Instead of a structure of flat sheets, a cylindrical structure, completely surrounding the groups of coils on each phase, may be used, in which case the proper potential distribution is such as will produce in the structure a field of logarithmic potential. Besides acting as insulation between the two groups of coils, the cylindrical structure forms part of the insulation to ground, but is hardly practicable on account of the high cost of insulating cylinders of very large diameter.

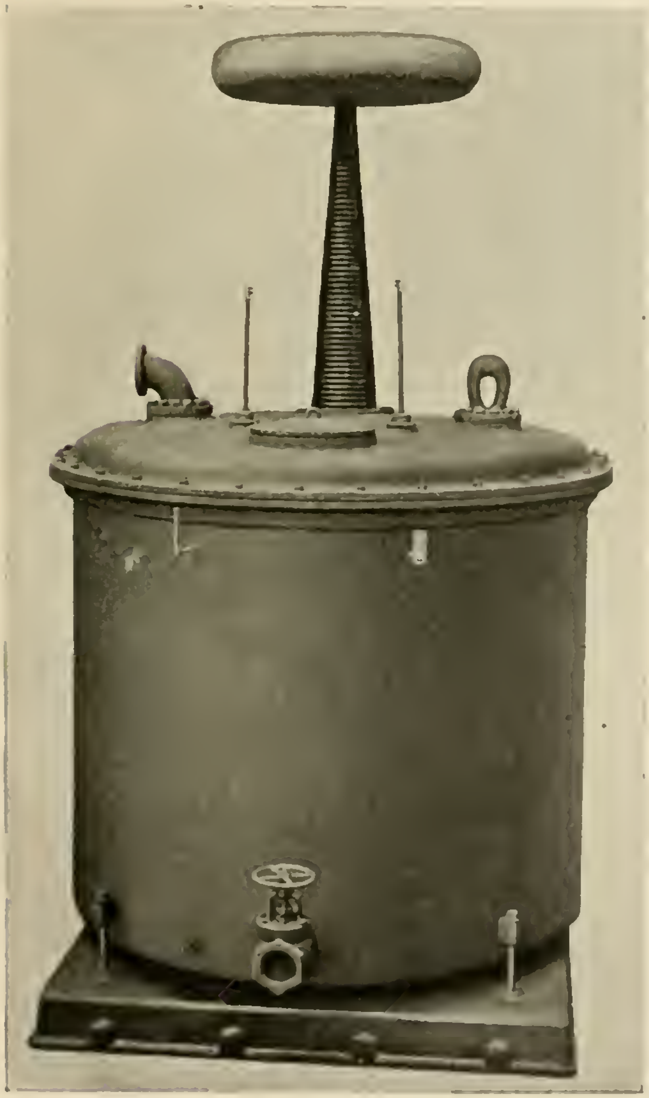


FIG. 10—ONE-HALF OF A ONE MILLION VOLT TRANSFORMER

One high tension terminal is grounded in each half.

CORE TYPE TRANSFORMERS FOR POLYPHASE CIRCUITS

Conditions of operation on polyphase circuits are somewhat different from those on single-phase circuits. A brief description will be given of the changes required to adapt the schemes for insulating transformers shown in the last section to polyphase circuits. For grounded three-phase star systems, the scheme shown in Fig. 6 may be used unchanged. For ungrounded star systems this design may be modified by the addition of extra insulation between core and windings to protect against stresses due to one wire becoming grounded. The insulation included in the coil grouping, in this case, should be considered as a separate region, because external bodies may have their potentials changed

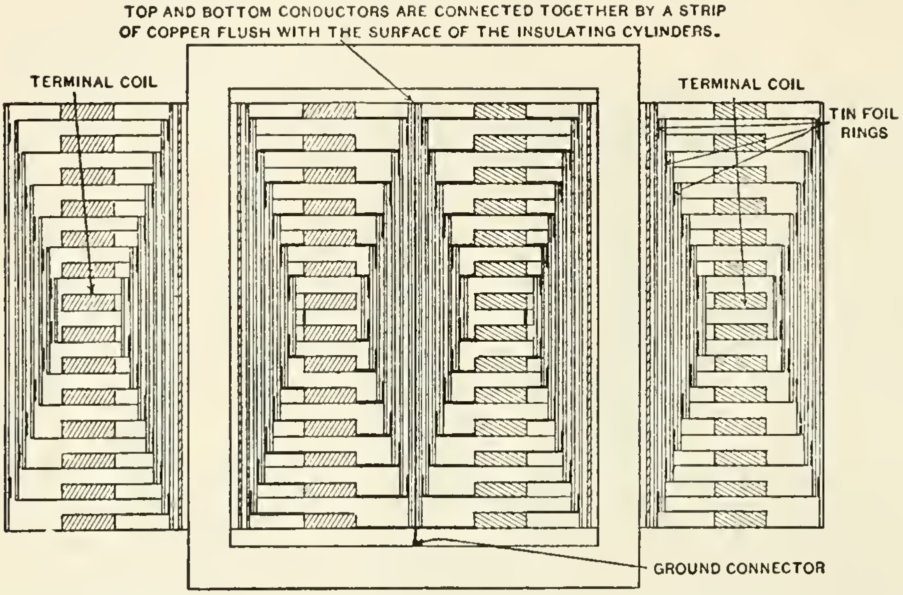

TOP AND BOTTOM CONDUCTORS ARE CONNECTED TOGETHER BY A STRIP OF COPPER FLUSH WITH THE SURFACE OF THE INSULATING CYLINDERS.
TERMINAL COIL
TERMINAL COIL
TIN FOIL RINGS
GROUND CONNECTOR

FIG. 11 INSULATION SCHEME AND COIL ARRANGEMENT FOR TRANSFORMER DESIGNED TO OPERATE WITH MIDDLE POINT GROUNDED

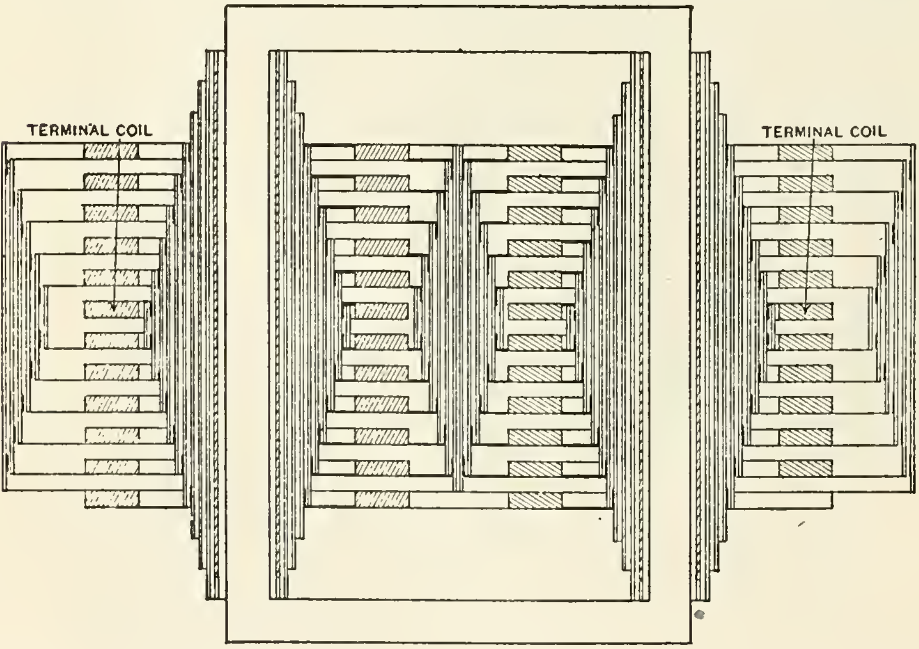


FIG. 12 INSULATION SCHEME FOR TRANSFORMER DESIGNED TO OPERATE WITH EITHER END GROUNDED

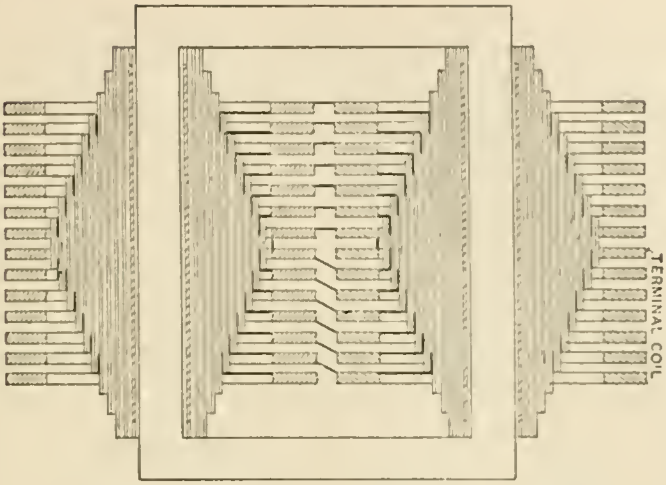


FIG. 13—INSULATION SCHEME FOR TRANSFORMER DESIGNED TO OPERATE ON STAR SYSTEM WITH UNGROUNDED NEUTRAL

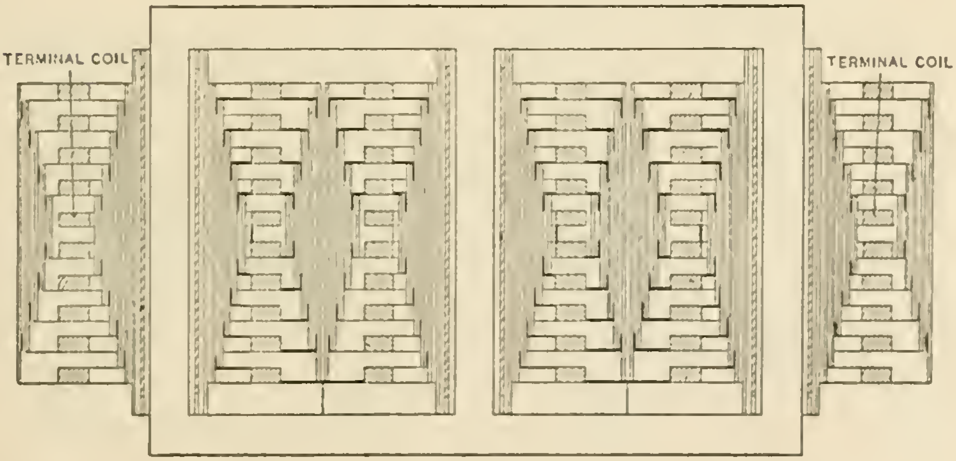


FIG. 14—THREE-PHASE TRANSFORMER TO OPERATE ON CIRCUIT WITH NEUTRAL POINT GROUNDED

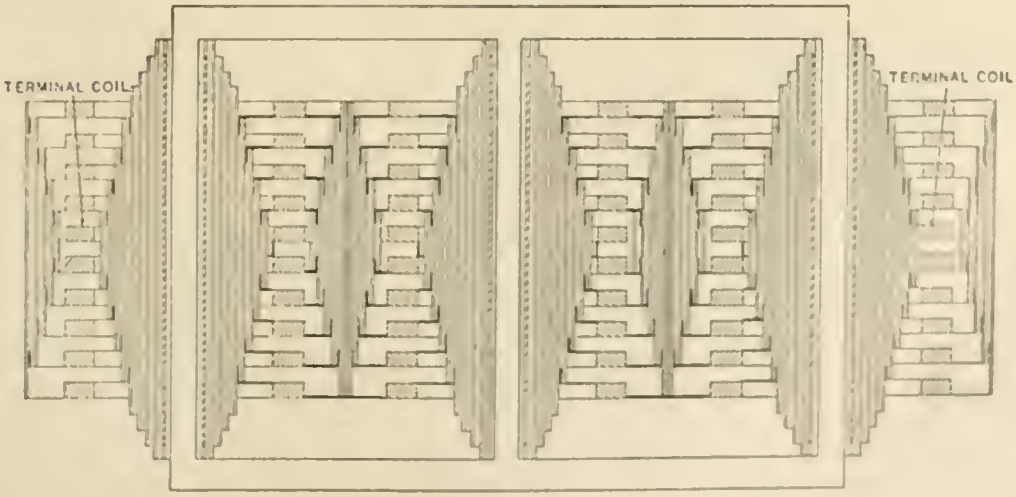


FIG. 15—THREE-PHASE TRANSFORMER DESIGNED TO OPERATE ON UNGROUNDED SYSTEM

relatively to the winding. Accordingly, the potentials of the windings themselves will also be raised or lowered relatively to external bodies. Therefore, to maintain the electric fields in the coil grouping and included insulating structures unchanged, it is necessary to consider all this space as a separate region. The intensity at each point within this region will then be independent of the potential of the coils relative to ground. For the region external to the winding included between the cylinder and coils of lowest potential of the winding system and the core, the proper potential distribution over the surface may be obtained by means of a system of concentric cylindrical condensers of equal capacity, varying in length by equal steps, according to the principle used in the condenser-type terminal. A scheme of insulation for such a transformer is shown in Fig. 13.

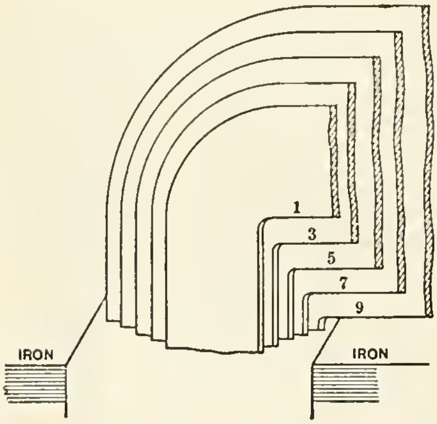


Fig. 16

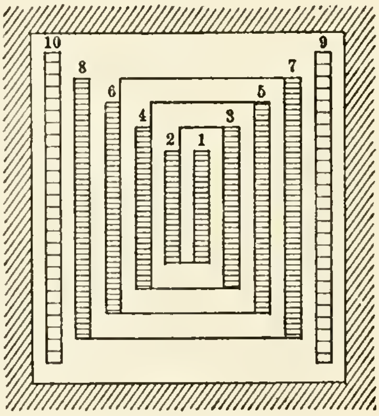


Fig. 17

For delta connection, transformers may have a modification of design shown in Fig. 12, additional strength between windings and core being secured to take care of stresses when one winding becomes grounded. Figs. 14 and 15 show polyphase transformers designed according to the principle.

SHELL TYPE TRANSFORMERS

The arrangement and connections of the high and low-tension coils of a shell type transformer designed to operate with one end permanently grounded are shown in Figs. 16 and 17. Here the coils themselves correspond to the equipotential surfaces of one region, their potentials decreasing progressively from No. 1 to No. 9. In the regions included between the coils and iron, the surface potential is determined by the coils themselves, so as to produce approximately a uniform field. Fig. 16 shows a section through the middle of the group at right angles to the plane of the core laminations, while Fig. 17 shows a section of one side of the coils parallel to the plane of the laminations. A single group only has been shown. If more groups are used, each group may be wound in the same way, and insulated from the adjacent low tension winding and iron, according to the potential of the outer coils.

A shell type transformer, designed to operate with its middle point grounded, may be made up of two groups connected as shown in Fig. 18, the inner coils of each group being the high potential coils, and the outer being connected to the iron and case and grounded.

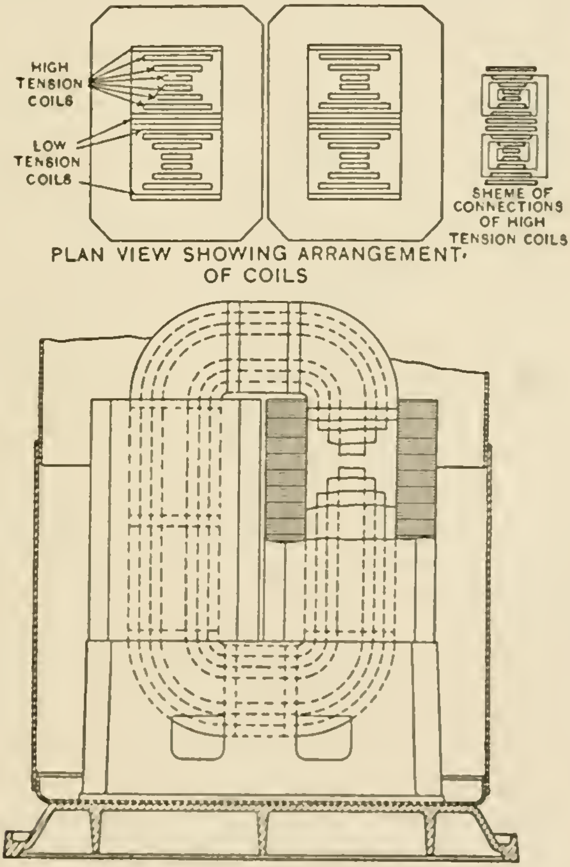

HIGH TENSION COILS
LOW TENSION COILS
SHEME OF CONNECTIONS OF HIGH TENSION COILS
PLAN VIEW SHOWING ARRANGEMENT OF COILS

FIG. 18—SHELL-TYPE TRANSFORMER DESIGNED TO OPERATE WITH MIDDLE POINT GROUNDED

For polyphase systems, modifications of the designs shown above may be used. These modifications are of the same nature as those required to adapt core type single-phase design to designs for operation on polyphase circuits, and need not be gone into any further.

APPLICATION OF THE PRINCIPLE TO THE DESIGN OF OUTLET TERMINALS AND INSULATORS

In core type transformers, designed according to the principle, the outlet terminal forms part of the insulation system of the transformer, and must be designed in accordance with the same principle. One way of doing this would be to produce within the body of the terminal a logarithmic potential by means of rings of tin foil connected to the proper points of the transformer winding. This method, however, is not convenient. A better plan is to obtain the required surface potential distribution by means of a system of concentric condensers.

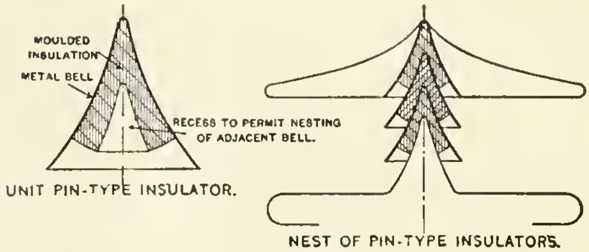
The condenser type terminal, as it is commonly called, affords a conspicuous example of the successful application of the principle stated in this paper. As commercially made, this terminal consists of a series system of concentric cylindrical condensers of equal capacity, so arranged that the ends of the conducting cylinders form, at the outer surfaces of the terminal, a potential distribution corresponding to that of a uniform field, the equipotential surfaces of which are at right angles to the axis of these cylinders. To conform therefore to the principle stated in this paper, the space external to the terminal must be bounded by two infinite parallel conducting planes perpendicular to the axis, one at the tip and the other at the end of the conducting cylinder of largest diameter, and connected to the conducting cylinders at these points. In practice, this condition is approximated by placing a disk-shaped conducting body at the end of the middle cylinder, and making the surface of the cover through which the terminal passes as free from projections and ridges as possible.

A comparative test has been made on a terminal of this type, first with a small disk, and then with a large one, which illustrates in a remarkable way the importance of the proper application of the principle. The terminal when tested with a small disk, at a potential above ground of 300 000 volts, showed signs of corona, which extended to the rings at the edges of the tin foil cylinders at 350 000 volts. At 400 000 volts, the whole terminal was lit up with corona. It was not found advisable to raise the voltage above 420 000 volts for fear of rupturing the terminal. The small disk was then replaced by a large one five feet in diametr and one foot thick with semi-circular edges. With this disk the terminal showed no signs of corona up to 573 000 volts. These potentials are those obtained by ratio. By a needle spark gap, the values indicated were 35 percent higher.

There are other ways of constructing a terminal, depending upon the same principle. For example, instead of using a system of concentric cylindrical condensers, a system of parallel disk condensers of equal capacity might be used, the diameter of the disks being such that the distribution of potential over the surface of the internal region of the terminal will correspond to a logarithmic potential, with proper relations between the inside conducting cylinder and the inside edge of the outer disk. The intensity within the terminal may be limited to any assigned value. A terminal designed in this manner would occupy more space than the condenser type terminal, but might have advantages where it is desirable to make the overall length as short as possible.

A transmission line insulator consists of a system of condensers in series. To obtain an equal division of potential difference between insulators, is not the only requirement of a successful design. This condition may actually be obtained, and yet the system of insulators will break down at a very much lower potential difference than the sum of the breakdown strengths of each insulator. The strength of the system may be increased by applying the principle stated in this paper. Accordingly, if the units of which the insulator is composed are equally spaced, and have each the same capacity, the high- and low-potential conducting surfaces which are insulated from each other by the insulator should be so designed as to give as nearly as practicable a uniform field corresponding to the potential distribution at the outer surface of the insulator. For example, Fig. 19 illustrates an element of an insulator, which consists of a metal bell, so designed that it may be used as the electrode of the adjacent insulator. A dielectric compound is moulded into the above mentioned bell, so that it will have a recess for the adjacent bell to nest into. The surface of the dielectric, which is intercepted between two adjacent bells, is moulded so as to conform to the lines of force of the electric field between the two adjacent bells. A nest of these may be used as a high-voltage insulator, and each insulator will take up approximately an equal share of the difference of potential, but in order to obtain the highest efficiency from the insulator, an arrangement of parallel discoidal-shaped electrodes, like those shown in Fig. 19, must be used. The external field will then be substantially uniform, and agree with the division of potential between the individual insulators. The efficiency of the combination is thereby increased in exactly the same way that the efficiency of a condenser type terminal as an insulator was increased by the addition of the large disk, namely, because it completed the surface distribution of the region surrounding the terminal in accordance with the principle.

A unit insulator, made according to the above plan, conforms to the law of similar fields. Thus, if the dimensions are doubled, the breakdown voltage is doubled. The cost of an insulator of this kind will vary approximately as the cube of the voltage. If, by some such method as that outlined in the last paragraph, the efficiency of a nest of insulators can be made to equal that of each individual unit, and if this can be done at a reasonable cost, then the cost of an insulator of this type will vary directly with the voltage for which it is designed. It is therefore obvious that an insulator, consisting of a nest of small insulators, would cost less than a large single insulator designed for the same voltage. The principle may be applied to suspension type insulators, also, as shown in Fig. 20. Other types of insulators besides those shown may also be assisted by the application of this principle, but the advantage to be gained is not so evident as in the type shown.



UNIT PIN-TYPE INSULATOR.

NEST OF PIN-TYPE INSULATORS.

Fig. 19

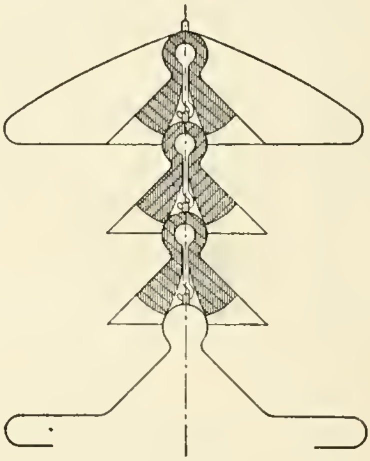


Fig. 20

MISCELLANEOUS APPLICATIONS

The well known principle of the guard ring is a particular case of the principle stated, and so also is the method of protecting instruments by means of grounded metallic coverings. The principles gives the method by which a given electric field may be maintained constant within an enclosed region, independent of the influence of external bodies. It may therefore be used to protect systems of charged bodies from the influence of other bodies. There seem to be many possible applications of the principle in high-voltage investigations.

NOTES ON ELECTRIC FIELD DISTRIBUTION[*]

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Professor of Physics, Lehigh University

In response to repeated requests for a detailed explanation of the electrostatic theory outlined and applied in the important paper by Mr. C. Fortescue, which was read before the American Institute of Electrical Engineers on March 14, the following discussion was prepared by Prof. Franklin. Mr. Fortescue's article on "A Study of Insulation Problems" in this issue contains the greater part of the paper mentioned.—(Ed.)

THE following propositions are extensively used in theoretical discussions of electrostatics:

a—Any equipotential surface may be wholly or in part replaced by a thin metal sheet without disturbing an electric field distribution. Thus Fig. 1 shows the lines of force between two metal cylinders *A* and *B*. The dotted line represents an equipotential surface, and this equipotential surface may be replaced wholly or in part by a thin metal sheet without disturbing the field between *A* and *B*.

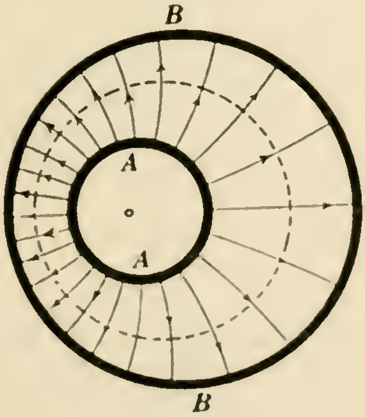

FIG. 1

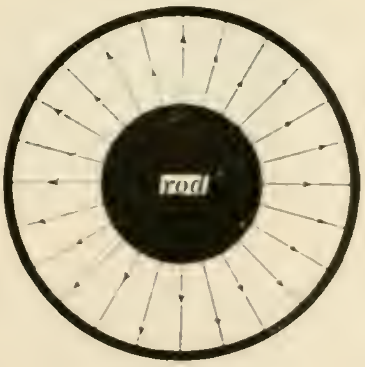

FIG. 2

b—A closed metal shell screens its interior from all outside electrostatic effects. This action of a metal shell may be understood in terms of a mechanical analogue as follows: Fig. 3 represents a mass of steel *B* completely separated from a surrounding mass of steel *A* by an empty space. The steel *B* remains unstressed however the steel *A* may be stressed, because stress cannot be transmitted across an empty space. Fig. 4 represents a mass of dielectric *B* completely separated from the surrounding dielectric *A* by a metal shell. The dielectric *B* remains unstressed however the dielectric *A* may be stressed, because electrical stress cannot be transmitted through metal. A very rapidly changing electrical stress can, however, be transmitted through metal to a slight extent.

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[*] From the *Journal of the Franklin Institute*, by permission

THE METHOD OF ELECTRICAL IMAGES

It is easy to formulate mathematically the distribution of electric field due to an electric charge which is thought of as being concentrated at a *point* or along a *line,* and the formulation of ideal problems of this kind furnishes the basis for the solution of some of the important practical problems in electric field distribution. Thus the fine lines in Fig. 5 represent the electric lines of force around a long, straight linear charge (a charge on a fine wire, the wire being very small and perpendicular to the plane of the paper). The potential at any point p in Fig. 5 is equal to

$$2Q \log_e r - 2Q \log_e r_0,$$

where r is the distance of the point p from the axis of the wire, Q is the charge per unit length of the wire, and r_0 is the distance from the axis of the wire to the chosen region of zero potential. This expression for the potential due to a linear charge is fully discussed in most text-books on electrostatics..

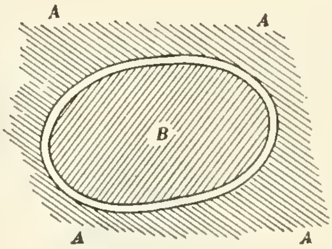

FIG. 3

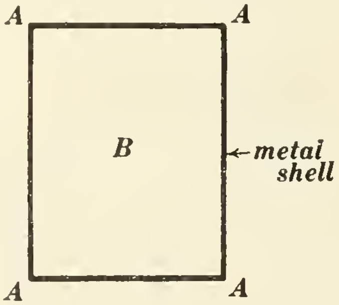

FIG. 4

The equipotential surfaces in Fig. 5 are cylinders, as represented by the dotted circles. If the inner circle, in Fig. 5, be replaced by a solid metal rod and the outer circle by a hollow metal cylinder, as shown in Fig. 2, the electric field in the intervening space will remain unaltered. Therefore the distribution of electric field around an ideal linear charge as shown in Fig. 5 leads to the solution of the problem of the distribution of electric field in the insulation of a cable as shown in Fig. 2.

Fig. 6 shows the electric field distribution between two long, straight, parallel equal but oppositely charged lines, the lines being at right angles to the plane of the paper. The expression for the potential at any point p in Fig. 6 is $2Q \log_e \left(\frac{r_1}{r_2}\right)$, where Q is the charge on the lines per unit length, positive on one line, negative on the other, r_1 is the distance of p from one line, and r_2 is the distance of p from the other line. This expression for the potential due to two linear charges is easily found from the expression for the potential due to one linear charge.

The equipotential surfaces in Fig. 6 are circular cylinders as represented by the dotted circles, and the equipotential surface midway between the linear charges is a plane. Fig. 7 shows two of the equipotential surfaces of Fig. 6 replaced by metal cylinders. The distribution of electric field between parallel metal cylinders as shown in Fig. 1 or Fig. 7 is the same as the distribution of electric field in Fig. 6. Therefore the mathematical formulation of Fig. 6 leads to the complete solution of the problem of electric field distribution around or between parallel cylinders.*

A great variety of particular problems relating to electric field distributions can be set up and solved by the method of images as exemplified by Figs 1, 2, 5, 6, and 7; and the origin of the term electric image may be understood with the help of Fig. 8. The electric field distribution between a linear charge *A* and an oppositely charged metal cylinder *BB* is identical to the electric field distribution which would be produced in the region *RR* by a line charge at *A* and an opposite line charge at *B'*. The easiest basis for the mathematical formulation of the field *RR* in Fig. 8 is, therefore, to think of the field as being due to the two linear charges *A* and *B'*. The fictitious linear charge *B'* is called the electric image of *A* with respect to the cylinder *BB*.

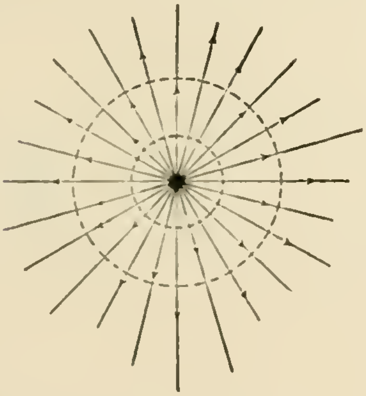

FIG. 5

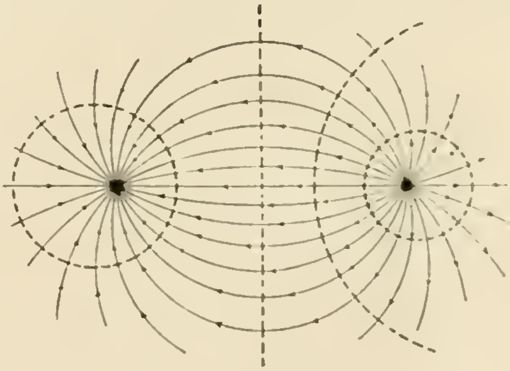

FIG. 6

THE PRODUCTION OF ANY DESIRED FIELD DISTRIBUTION IN A REGION BY THE CREATION OF PROPER POTENTIAL VALUES EVERYWHERE OVER THE BOUNDARY OF THE REGION

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*Approximate formulae are nearly always used in connection with the problem of parallel cylinders, however, because the rigorous formulas are rather complicated, as will be understood by reading pages 273 to 277 of Franklin's "Electric Waves."

The distribution of electric field in a region depends upon two things; namely, (*a*) the potential values over the boundary of the region and (*b*) the distribution of electric charge in the region. *When there is no charge in the region the boundary values of potential determine the field distribution.* Therefore, if it is desired to produce any assigned field distribution in a given range (a field distribution which is not associated with electric charge in the region, or, as it is usually expressed, an electric field which has no divergence[‡] in the region), it is sufficient to create the proper potential values over the boundary of the region.

Example 1—Fig. 9 represents the lines of force surrounding a linear charge. The dotted circle in Fig. 9 represents a cylinder parallel to the linear charge. Imagine this cylinder to be made of narrow insulated strips of metal as represented by the separate dots of the circumference, and imagine each strip to be brought by proper means to a potential equal to the potential at the strip due to the linear charge in Fig. 9. We would thus have the potential fixed at every point on the dotted cylinder in Fig. 9, and the electric field distribution inside of the cylinder would be as shown in Fig. 10, irrespective of the electric field outside of the cylinder. Fig. 10, therefore, is an example of the production of a desired electric field distribution in a given region by bringing the various parts of the boundary of the region to the proper potential values.

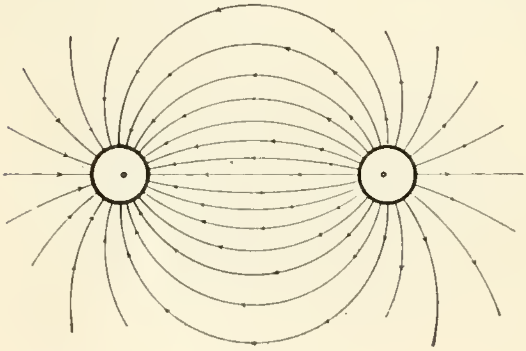

FIG. 7

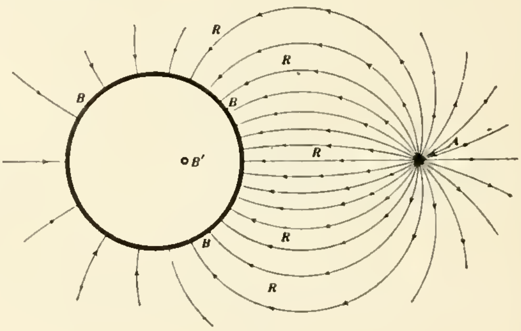

FIG. 8

Example 2—A metal sheet *AA* (Fig. 11) is at zero potential, and a series of insulated metal strips *BB* very close together and perpendicular to the plane of the paper are brought by proper means to potential values such that the potential V_p of any strip is proportional to its distance x from AA. Under these conditions the region between AA and BB will be a uniform electric field, as indicated by the lines of force in Fig. 11.

[‡] A very simple discussion of the important ideas of *divergence* and *curl* is given in Chapter IX of Franklin, MacNutt and Charles's "Calculus," published by the authors, South Bethlehem, Pa., 1913.

The method illustrated in Figs. 10 and 11 for producing any assigned electric field distribution in a given region is used by Mr. Fortescue in the designing of insulating structures. Let it be required, for example, to produce a uniform electric field parallel to the y-axis in the region of the coarse lines of force in Fig. 12, and a cylindrically radiating electric field in the region of the fine lines of force in Fig. 12. By cylindrically radiating field is here meant a field which radiates from the y-axis in an uncharged region.

Let us assume that the cylinder of radius r_0 and the end disks dd are at zero potential, and let us consider the potential

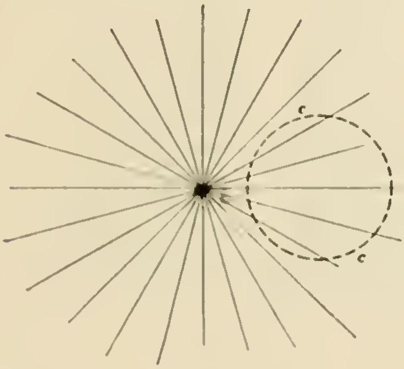

FIG. 9

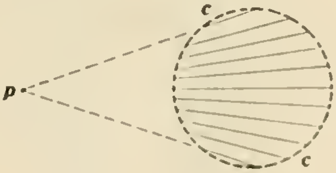

FIG. 10

at any point p of which the co-ordinates are x and y. The potential at p due to the radial field is

$$k \log_e x - k \log_e r_0,$$

where k is a constant, on the assumption that the radial field reaches to p; and the potential at p due to the uniform field is $fl - fy$, where f is the intensity of the uniform field. The locus of the points where the two fields give the same potential is represented by the dotted curve in Fig. 12, and its equation is gotten by equating the above expressions for potential.

Now, in order that the two fields as indicated in Fig. 12 may be actually obtained, it is sufficient to have the tube and the end disks at potential zero, to have the middle disk at potential fl, and to provide a number of rings of tin foil (as represented in section by the dots of the dotted curve in Fig. 12) along the common boundary of the two fields, these rings being brought by proper means to potentials which conform to both fields.

The radial field of which the potential is

$$2Q \log_e r + \text{a constant}$$

is the only type of field which can radiate from an axis in a region where there is no charge. If it is desired to produce a radial electric field which remains constant in value with increasing distance from the axis, it is necessary to provide a series of coaxial cylindrical leaves of metal as shown in Figs. 13 and 14. The theoretically correct shape of the curve *cc* in Fig. 13 is an equilateral hyperbola, because the successive tin-foil cylinders must have the same area. No attempt is made in Fig. 13 to represent the distribution of the electric field in the external region surrounding the bushing. As a matter of fact, this electric field is very greatly concentrated in the region immediately surrounding the rod at the ends of the bushing.

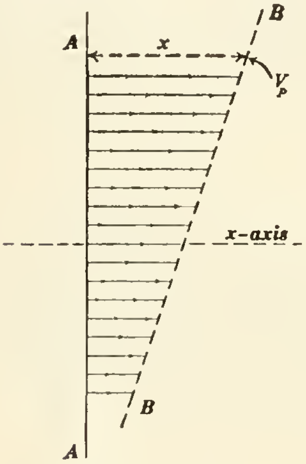

FIG. 11

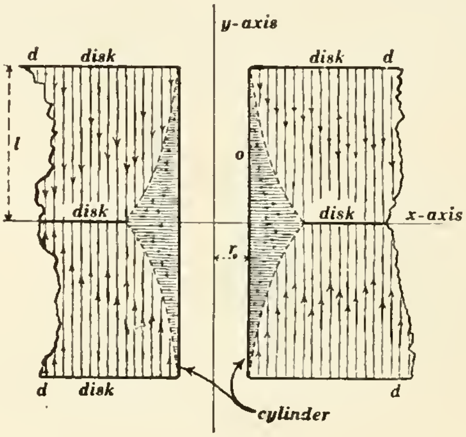

FIG. 12

Fig. 14 shows the method suggested by Mr. Fortescue for eliminating the concentration of electrical stresses at the ends of the bushing in Fig. 13. There is a constant potential difference between successive tin-foil cylinders in Fig. 14, and therefore, if the potentials of the successive tin-foil cylinders are to be conformable to the uniform electric field which is represented by the coarse lines of force in Fig. 14, it is necessary to terminate the cylinders along the dotted straight lines as shown in Fig. 14. With this arrangement, however, the tin-foil cylinders do not all have the same area; and, therefore, to provide for equal potential steps between successive tin-foil cylinders, it is necessary to connect the successive cylinders to the proper points in the winding of the transformer.

UNIFORM ELECTRIC FIELD MODIFIED BY A CYLINDRICAL CONDUCTOR

Fig. 15 shows the lines of force in the neighborhood of a metal cylinder of radius r in a region which would be a uniform field at right angles to the axis of the cylinder if it were not for the distorting influence exerted on the field by the metal cylinder. The mathematical formulation of the field distribution in Fig. 15 is accomplished by the method of images as follows:

Consider two opposite linear charges parallel to each other and at a distance dx apart, and let $+Q$ and $-Q$ be the charges per unit length, where $Q.dx$ is a finite quantity. Such a pair of linear charges is called a *linear doublet,* and the product $Q.dx$ $(=M)$ is called the *moment* of the doublet. The potential at a point due to a linear doublet is found with the help of Fig. 16 as follows: The potential at the point p in Fig. 16 due to the linear charge $+Q$ is $2Q \log_e (r + \Delta r)$,§ and the potential at p due to the linear charge $-Q$ is $-2Q \log_e r_o$. Therefore the net potential at p due to the doublet is

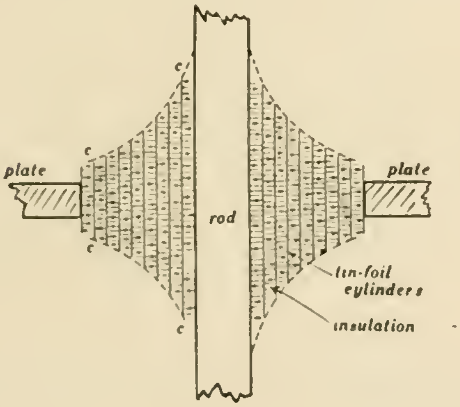

FIG. 13

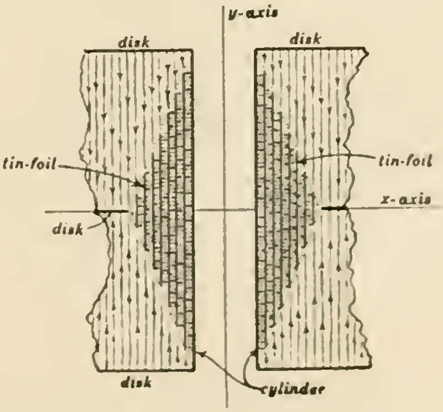

FIG. 14

$$2Q\ [\log_e (r + \Delta r) - \log_e r] = 2Q \frac{d\ (\log_e r)}{dr} . dr$$

$$= 2Q \frac{1}{r} . dr = 2Q \frac{1}{r} \cos \Theta . dx = 2M \frac{\cos \Theta}{r}.$$

The finding of the mathematical formula for the distribution of potential in Fig. 15 depends upon the finding of an expression for potential which will give a constant potential over the surface of the cylinder, but which at great distances from the cylinder will reduce to the potential which is associated with the uniform field. This condition is met by superposing the potential due to a linear doublet upon the potential which is associated with the uniform field.

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§The undetermined constant $2Q \log_e r_o$ is here ignored because it drops out anyway.

The above expression for the potential of a linear doublet is based upon the choice of the y-axis in Fig. 15 as the region of zero potential, and the expression for the potential which is associated with the uniform field in Fig. 15 is $-fx$, where f is the intensity of the field. This field is directed toward the left in Fig. 15. Therefore the potential due to the uniform field and to the linear doublet together is:

$$V = 2M\frac{\cos\theta}{r} - fx \qquad (1)$$

But $x = r\cos\theta$, so that this equation becomes:

$$V = \left(\frac{2M}{r} - fr\right)\cos\theta \qquad (2)$$

If r is the radius of the metal cylinder, this equation expresses the potential of the metal cylinder. But the metal cylinder has zero potential, because we have chosen the y-axis as the region of zero potential in the above discussion. Therefore, V as given by equation 2 must be zero when r is the radius of the metal cylinder. Therefore the expression in the parenthesis must be equal to zero, or we must have:

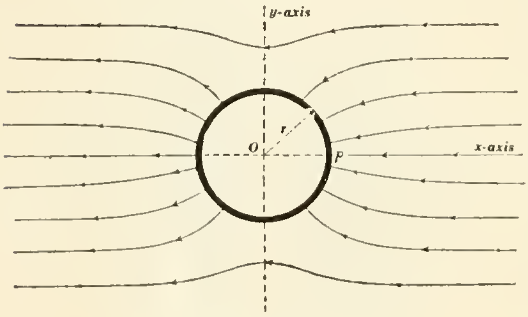

FIG. 15

$$M = \frac{1}{2}fr^2 \qquad (3)$$

which gives the moment of the linear electric doublet to be placed along the axis of the metal cylinder in Fig. 15 to give (when the cylinder is taken away) the field distribution which exists in Fig. 15 in the region outside of the cylinder. The linear doublet is the image in the metal cylinder of the external influence which is the cause of the uniform field in Fig. 15.

It is evident, from Fig. 15, that the presence of the metal cylinder produces a concentration of the electrical stress, the maximum of stress being at the point p. The field intensity at p may be considered in two parts, namely, (a) the part $-f$ which is associated with the uniform field, and (b) the part which is associated with the linear doublet. This second part is found by taking the value of $\frac{dV}{dx}$ at p, where V is the potential due to the doublet. But at p (and all along the x-axis) the potential due to the doublet is

$$V = \frac{2M}{x}$$

so that

$$\frac{dV}{dx} = -\frac{2M}{x_2} = -\frac{2M}{r_2}$$

because $x = r$ at p. Substituting the value of M from equation 3, we get $-f$ for the intensity at p of the field due to the doublet. Therefore the total intensity of the field at p is equal to $2f$, and it is, of course, negative, being directed toward the left in Fig. 15.

In the above discussion the radius of the metal cylinder may be anything whatever. Therefore if a wire of any radius is stretched across a region which, but for the presence of the wire, would be a uniform field of intensity f at right angles to the axis of the wire, then the presence of the wire causes a local concentration of electric stress (at the point p in Fig. 15), and the maximum electrical stress thus produced is $2f$.

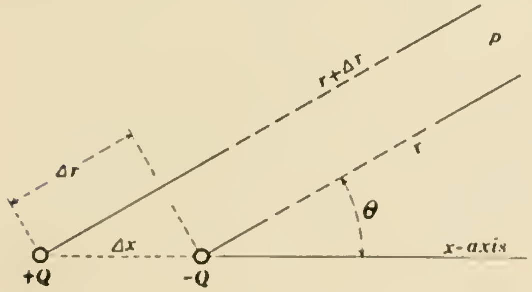

FIG. 16

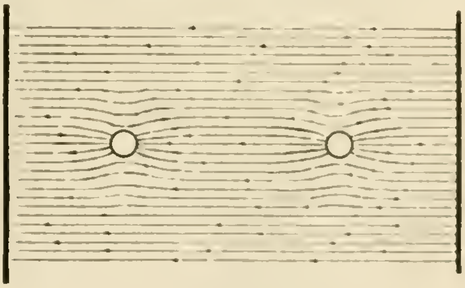

FIG. 17

In the case of two ordinary line wires the electrical stress is greatly concentrated near the wires, especially if the wires are small. Indeed, the maximum stress in this case is:

$$f_{max} = \frac{E}{2R \log_e\left(\frac{D}{R}\right)}$$

where R is the radius of the wires, D is their distance apart center to center, and E is the voltage between the wires. Now this maximum stress may be very large indeed for given values of E and D, but the maximum stress is reduced to $2(E : D)$ by superposing a uniform field of intensity $(E \div D)$ as indicated in Fig. 17. This exemplifies Mr. Fortescue's method of doing away with excessive concentrations of stress by the superposition of a uniform field.

EFFICIENCY AND COST OF ELECTRICAL HEATING†

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THE transformation of electrical energy into heat is known to take place at an efficiency of one hundred percent and is is therefore not within our power to make improvements in this direction. We can, however, increase the efficiency of the methods applied for transmitting the electrically generated heat into the substance, the temperature of which is to be raised. The types of heaters, used for transforming electricity into heat have been described in a previous article,* but little has been stated about the methods of carrying the electrically generated heat to the point where it is required. Since the efficiency of all electrical heating appliances is more or less controlled by these methods, of which there are four, they will be discussed a little more carefully.

The first method connects the substance, which is to be heated, into the electrical circuit of the heater and produces the heat in the substance itself. This however is only possible, if the latter is an electrical conductor and if general conditions permit its connection into the circuit. As the heat is generated in the very material, for which it is required, all transmission losses are eliminated, resulting in an efficiency of one hundred percent.

The induction furnace** applies this principle, by using the furnace charge as the secondary of the transformer. The total efficiency of such a furnace however is not more than seventy-five percent, comparatively large losses being suffered in the transformer and by some heat escaping from the charge through the furnace walls into the surroundings. (To some extent, electric arc furnaces also generate heat in the charge, due to the resistance offered to the current passing through.) The electric welding machine† applies the same method of producing the heat directly in the spot, where it is required i. e., in those portions of the metal, which are to be welded together. The losses are confined to the transformer losses and a small amount of heat lost into the surroundings, the total efficiency being over 90 percent.

The electric fuse is another device generating the heat in the substance itself. In this case the only loss suffered is the heat passing into the surroundings, the efficiency, considering the fuse as a heating appliance, being over ninety percent.

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†This is the third and concluding article of a series on electric heating. The previous articles appeared in the April and May issues.

*See the JOURNAL for April, 1913, p. 353.

**See the JOURNAL for April, 1913, p. 347.

†See the JOURNAL for April, 1913, p. 352.

The second method arranges the substance which is to be heated in such a manner that it surrounds the electrical heater entirely. Necessarily all heat generated and not retained by the heater itself must be utilized. For all practical requirements, this method has also an efficiency of one hundred percent. All air heaters,* such as luminous radiators, stoves, street car heaters, belong in this class, as the air, which is to be heated, completely surrounds these devices, and necessarily receives all the heat and the efficiency must be one hundred percent. The same can be said about all immersion heaters. As the name implies, they are immersed into and completely surrounded by the substance, which is to be heated, in most cases a liquid. They are made in the form of coils, discs, cylinders, tubings, and are used for some types of water-heaters, sterilizers and similar appliances. Their total efficiency depends entirely upon the provisions for preventing the substance from losing heat into the surroundings. With proper protection, it is possible to obtain efficiencies as high as ninety-nine percent. The spark plug also belongs to this group, as it is always so located that its spark gap is enveloped by the gases, which are to be ignited. Its efficiency is thus 100 percent.

The third method is employed when the electrical heater cannot be arranged as pointed out above. Then it becomes necessary to place it as close to the substance as possible in such a manner that, by providing proper heat insulation, a minimum amount of heat passes from the heater directly into the surroundings. Devices, built on these lines and carefully designed have efficiencies from eighty-five to ninety-five percent. All vessels, fireless cookers, baking ovens, enameling ovens, hot closets, frying kettles, melting pots, oil tempering baths, and in fact, most domestic and industrial devices, equipped with individual electrical heaters, which are so arranged that it is difficult to deliver heat directly into the surroundings, belong to this class. Resistance furnaces and electric arc furnaces are also constructed on the same principle, however their efficiency does not exceed seventy-five percent, due to their heat losses into the surroundings being comparatively high on account of their high working temperature.

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*See the JOURNAL for April, 1913, p. 348.

The fourth method covers all those cases, in which it is impossible to prevent a considerable loss of heat into the surroundings, due to the character of the work which is to be performed. The efficiency of these devices naturally is low compared with others, nevertheless it ranges between thirty-five and sixty percent. Ranges, broilers, disc stoves, toaster stoves, cigar lighters, sad irons, soldering irons, branding irons, heating pads, foot warmers, and cauterizing instruments are representatives of this class.

COST

To speak about the cost of electric heating without making a comparison with those methods which have heretofore controlled the field, would be practically useless, because no one cares to adopt something new, unless the change from the old thoroughly-tried-out methods is advantageous in one way or another. Table I below is made to enable such a comparison in a general way.

TABLE I—COMPARATIVE COST OF HEAT GENERATED BY COAL, GAS AND ELECTRICITY.

Coal—Develops at an average a heat of 12 000 b.t.u. per lb. The efficiency of coal burning heating apparatus averages about 10 percent. Effective heat obtained from 1 lb. of coal=1 200 B.t.u.; from 1 short ton of coal=2 400 000 B.t.u.

Gas—Develops at an average a heat of 660 B.t.u. per cu ft. The efficiency of gas burning heating appartaus averages about 20 percent. Effective heat obtained from 1 cu. ft. of gas=132 B.t.u.; from 1 000 cu. ft. gas=132 000 B.t.u.

Electricity—Develops a heat of 3 413 B.t.u. per kw.-hr. The efficiency of electrically heated apparatus averages about 80 percent. Effective heat obtained from 1 kw-hr.=2 730 B.t.u.

Based on these figures, the same amount of useful or effective heat is generated by

1 kw-hr. or 20 cu. ft. of gas or 2¼ lb. of coal.

TABLES OF COMPARISON

showing prices at which electricity would have to be sold, to compete with coal and gas, if there would be no other advantage in using electrically generated heat.

Coal—	Electricity	Gas—	Electricity
per ton.	per kw-hr.	per 1 000 cu. ft.	per kw-hr.
$1.50—	0.17 cents	$0.10—	0.2 cents
2.00—	0.23 cents	0.20—	0.4 cents
2.50—	0.28 cents	0.30—	0.6 cents
3.00—	0.34 cents	0.40—	0.8 cents
3.50—	0.39 cents	0.50—	1.0 cents
4.00—	0.45 cents	0.60—	1.2 cents
4.50—	0.51 cents	0.70—	1.4 cents
5.00—	0.57 cents	0.80—	1.6 cents
5.50—	0.62 cents	0.90—	1.8 cents
6.00—	0.68 cents	1.00—	2.0 cents
		1.25—	2.5 cents
		1.50—	3.1 cents
		1.75—	3.6 cents

Electricity for heating purposes is sold at the present time to the general public at prices ranging from three to ten cents per kilowatt-hour, a fair average being five cents; large consumers enjoy prices from one and one-half cents to five cents, and in the immediate neighborhood of a few hydro-electric plants large quantities of energy can be purchased as low as three-quarter cents per kilowatt-hour. Large mills, under very favorable conditions, can produce electrical energy for their own use for as low as one-fourth cent per kilowatt-hour. These figures show that the cost of electrical energy for generating heat, with few exceptions, is higher than coal and gas and that other reasons for its adoption must exist. The most important reasons are:—

1—The possibility of producing temperatures considerably higher than can be obtained with coal, gas or any other heat producing method.
2—The possibility of fitting electrical heaters into places, where other heating devices cannot be located.
3—The possibility of controlling the temperature absolutely.
4—The superior quality of the product.
5—The saving in labor, either by dispensing with it altogether or by replacing expensive skilled hands by cheap unexperienced help.
6—The reduced fire risk.
7—The increased cleanliness, improved sanitary conditions and a minimum increase of the temperature in the surroundings.

How these advantages often more than balance the higher cost of the electric current cannot be expressed in general rules or formulae and thus the conditions under which an electrical heating appliance can be used to advantage must be studied carefully for each individual case. This can best be explained by a number of examples.

1—*The possibility of producing temperatures considerably higher* than can be obtained with coal, gas or any other heat producing method, enables the production of materials, such as carborundum, tungsten, artificial graphite, artificial emery, calcium carbide, ferro alloys and numerous others. The electric furnace employed in this work practically has created an entirely new industry; before the application of electricity was possible, the materials just named could not be produced at all or the processes known were not commercial.

2—*The possibility of fitting electrical heaters into places where other heating devices cannot be located* is clearly demonstrated by surgical and dental tools, by the self-contained curling iron and the heating pad. In all four cases it is impossible to locate any other kind of a heating device inside the appliances, due to lack of space. If electric current cannot be had, then the tools in question must be heated over a flame, the heating pad must be replaced by a hot water bag and the heat thus supplied steadily decreases in amount, lasting for a limited time only; the electrical devices on the other hand retain an even temperature, as long as the current is turned on. This advantage more than pays for the difference in cost.

3—*The possibility of controlling the temperature absolutely* is very important in heating steel to the critical temperature point for the purpose of hardening. A difference of only a few degrees influences the quality of the product very much; such an error can be avoided in the electric furnace with a great deal more ease and accuracy than in any other type and the higher grade of steel resulting offsets the slightly increased cost.

4—*The superior quality of the product* is well illustrated by the electric baking and roasting oven, applied in commercial cooking. The electric oven is the only type of oven in existence that gives the same measured amount of heat every time, distributes that heat evenly and is entirely free from draught. Having once made a few tests on an oven, one has the certainty of obtaining the same conditions every time. All meat will be roasted exactly alike, the loaves of bread will all be of uniform quality, points of vital importance, when large numbers of people are to be fed.

5—*The saving in labor* by applying electrical heat very often pays for the higher cost of the current. A trolley car heated electrically does not require any attention whatsoever, as the conductor merely has to turn the switch for obtaining heat. If stoves are used instead, the cheapness of coal is well balanced by the cost of handling coal and ashes and increased repairs, not taking into consideration that electrical heat is more uniform and is not accompanied by dust and smoke.

6—*As the fire risk* by using electrical heaters in places, where explosives or inflammable material is handled, is considerably reduced, the fire insurance companies make allowances in their rates and in some cases permit nothing but electrical heaters.

Finally, *increased cleanliness, improved sanitary conditions and a minimum increase of the temperature in the surroundings* very often give the electrical heater the preference over others regardless of the higher cost of current. This is best illustrated by the complete line of dining-room cooking appliances, such as toaster stoves, disc stoves, water-heaters, percolators, teapots, chafing dishes, frying pans and others, the use of which increases every year and which practically have no competition, as it is safe to say that the few percolators and chafing dishes heated by alcohol flame are a matter of the past.

This fact that, in most cases, electrical energy is too expensive for heating purposes, unless advantages other than cost are offered at the same time, has clearly defined the lines on which the art had to be developed in order to be a success. What actually has been accomplished may be judged from the list of commercial apparatus available as listed in Table II. This Table shows the amount of maximum energy consumed by each appliance, which permits an approximate calculation of the cost of operating, and it also indicates that electrical heating appliances have been standardized for a great variety of domestic and industrial purposes. In fact it is safe to predict that this development will continue to go on and on and that electrical heating will become quite general in a not too distant future, just as the electric light has superseded the gas light and as the gas range has replaced the coal range, regardless of higher cost of operating.

TABLE II—CAPACITIES OF ELECTRICAL HEATING DEVICES

The heater capacities, given in this table, are used by the leading American and European manufacturers and represent a fair average of standard practice. The figures indicate the maximum amount of energy required to raise the temperature to the desired point, less energy, of course, being required to maintain this temperature. When two figures are given, both are used, one for slow and one for quick action.

Air Heaters:—		
Convectors, smallest size, three heats	600	Watts
Convectors, largest standard size, three heats	18 000	"
Luminous radiators, smallest size, one bulb, single heat	250	"
Luminous radiators, largest standard size, four bulbs, two heats	2 000	"
Quartzalite radiators, smallest size, two heats	600	"
Quartzalite radiators, largest standard size, two heats	1 600	"
Show window convectors, capacity per running yard, single heat	300	"
Street car heaters, smallest unit, three heats	250	"
Street car heaters, largest standard unit, three heats	450	"
Air humidifiers (bronchitis kettles)	600	"
Back rounders, for books, three heats	300	"
Beer vat driers, three heats	3 000	"
Boilers, double (cereal cookers), small size 3 pints, three heats	440	"
Boilers, double, largest standard size 6 quarts, three heats	1 300	"
Boilers, hot water, heaters inside, smallest size 3 gallons, three heats	500	"
Boilers, hot water, heaters inside, largest standard size 100 gallons, three heats	14 000	"
Branding irons, single heat	150 to 660	"
Broilers, in oven shape, smallest size 16"x14", two heats	2 500	"
Broilers, largest standard size, 32"x30", two heats	10 000	"
Broilers, open plates, smallest size 8"x7¾", single heat	660	"
Broilers, open plates, largest standard size 39"x10", two heats	6 400	"
Cauterizing instruments, without loss in controller	30 to 75	"
Celluloid heaters, three heats	900	"
Chafing dishes, smallest size 2 pints, three heats	250	"
Chafing dishes, largest standard size 3 pints, three heats	500	"
Chocolate warmers, for maintaining chocolate in a fluid state for dipping, smallest size 12"x6½"x5", three heats	220	"
Chocolate warmers, largest standard size, 14¼"x7⅝"x6", three heats	[illegible]	"
Cigar lighters, continuous service, single heat	[illegible]	"
Cigar lighters, intermittent service, single heat	75 to 100	"
Circulation water heaters, used in connection with boilers, smallest size, two heats	1 800	"
Circulation water heaters, largest standard size, two heats	3 000	"
Coffee percolators, smallest size 1 pint, single heat	250 to 400	"
Coffee percolators, largest standard size 4 pints, three heats	350 to 500	"
Coffee percolators, restaurant size, 12 quarts, single heat	750	"
Coffee roasters, smallest size 2 to 3 lbs., three heats	800	"
Coffee roasters, largest standard size 8 to 10 lbs., three heats	3 600	"
Coffee urns, smallest size 2 gallons, three heats	1 400	"

Coffee urns, largest standard size 5 gallons, three heats	2 500	Watts
Combs, heated, single heat	50	“
Corn poppers, 1 quart, single heat	300	“
Cooking vessels with covers, smallest size 2 pints, three heats	600	“
Cooking vessels, largest standard size, 26 gallons, three heats	7 500	“
Corset irons, 8½ lbs., two heats	500	“
Cosmetic heaters, single heat	25	“
Curling irons, self-containing, single heat	20	“
Curling irons, heater in separate tubing, single heat	60 to 400	“
Dentist's tools, such as root canal driers, guttapercha instruments, bleacher points, wax spatulas, hot air syringes without loss in controller	6 to 30	“
Disc stoves, smallest diameter 3″, single heat	100 to 400	“
Disc stoves, largest standard diameter 20″, three heats	2 700	“
Distilling apparatus for ether, three heats	300	“
Distilling apparatus for water, smallest size 1 quart per hour, single heat	1 000	“
Distilling apparatus, largest standard size 8 quarts per hour, single heat	6 000	“
Domestic flat irons, smallest size 3 lbs., single heat	200 to 250	“
Domestic flat irons, largest standard size 9 lbs., single heat	400 to 675	“
Drag irons, smallest size 30 lbs., single heat	1 400	“
Drag irons, largest standard size 50 lbs., single heat	1 600	“
Egg boilers, smallest size 1 egg, single heat	200	“
Egg boilers, largest standard size 6 eggs, three heats	360 to 600	“
Finishing (polishing) irons, smallest size 4 lbs., two heats	250 to 380	“
Finishing (polishing) irons, largest standard size 5½ lbs., two heats	450	“
Fireless cookers	150 to 660	“
Flask heaters, 8½″ diameter, three heats	500	“
Flat plates, rectangular or oval, used as food warmers, griddle plates, laboratory plates, glue plates, smallest size 4x4″, three heats	60	“
Flat plates, largest standard size 80x40″, three heats	4 500	“
Foot warmers, smallest size 9″x10″, single heat	50	“
Foot warmers, largest standard size 10x12″, three heats	400	“
Frying pans, round, smallest diameter 4″, single heat	300	“
Frying pans, largest standard diameter, 12″, three heats	1 800 to 2 000	“
Frying pans, rectangular, with cover, smallest size 10x6½x5″, three heats	1 000	“
Frying pans, rectangular, with cover, largest standard size 24x12x5″, three heats	3 300	“
Furnaces for dentists, with controller	500	“
Furnaces for heat treatment of tool steels and other metallurgical work		
1 800° F. maximum, smallest size	450	“
largest standard size	4 150	“
2 000° F. maximum, smallest size	650	“
largest standard size	15 000	“
3 600° F. maximum, smallest size	10 000	“
largest standard size	75 000	“
Furnace, Héroult 15-ton steel, with controller	1 500	Kw.
Furnaces, vacuum type, for laboratory research work—		
5 cu. in. capacity, 5 600° F. maximum	15	Kw.
125 cu. in. capacity, 3 100° F. maximum	60	Kw.
Glove form heaters, single heat	50	Watts
Glue cookers with circulation water heaters, smallest size 3 gallons, three heats	1 800	“
Glue cookers, largest standard size 25 gallons, three heats	7 200	“
Glue pots with immersed heaters—		
smallest size ½ pint, three heats	150 to 330	“
largest standard size 5 gallons, three heats	2 500	“
Gold annealers for dentists with controller	400	“
Goose irons for tailors, smallest size 12 lbs	600 to 770	“
Goose irons, largest standard size 25 lbs	825	“
Hat brim irons, single heat	50	“
Hat form heaters, three heats	500	“
Hatters' irons, 9 to 15 lbs., two heats	450	“
Heating pads, smallest size 11x15″, three heats	50	“
Heating pads, largest standard size 24x60″, three heats	400	“
Hot air blowers, smallest size, two heats	500	“
Hot air blowers, largest standard size, two heats	1 400	“
Hot water cups, smallest size ½ pint, single heat	150	“
Hot water cups, largest standard size 2 pints, single heat	500	“
Hot water (tea kettles), smallest size 1 pint, single heat	250 to 300	“
Hot water (tea kettles), largest standard size 2 quarts, three heats	750	“
Hot water pitchers, smallest size 1 quart, single heat	600	“
Hot water pitchers, largest standard size 3 quarts, single heat	660 to 10 000	“
Hot water tanks for manufacturing purposes, smallest size 26 gallons, two heats	4 500	“
Hot water tanks, largest standard size 52 gallons, two heats	10 000	“
Immersion coils, smallest size 6½″ diameter, three heats	440	“
Immersion coils, largest standard size 11″ diameter, three heats	2 500	“
Immersion heaters, cylindrical type, smallest size 2¾″ diameter, three heats	300	“

		Watts
Immersion heaters, cylindrical type, largest standard size 20" diameter, three heats	10 000	"
Immersion disc heaters, smallest size 3" diameter, two heats	150	"
Immersion disc heaters, largest standard size 8" diameter, two heats	660	"
Immersion tube heaters, smallest size, single heat	170	"
Immersion tube heaters, largest standard size, single heat	660	"
Inhaling apparatus, smallest size ½ pint, single heat	100	"
Inhaling apparatus, largest standard size 2½ pints, three heats	800	"
Instantaneous hot water heaters, smallest size ½ pint per minute, temperature increase 68° F.	600	"
Instantaneous hot water heaters, largest standard size 10 quarts per minute, temperature increase 136° F.	24 000	"
Ironing machine (mangles), smallest size 40" long, three heats	2 400	"
Ironing machine, largest standard size 80" long, three heats	6 400	"
Lace iron, single heat	70	"
Machine irons for tailors, with controllers, smallest size 12 lbs.	770	"
Machine irons for tailors, with controllers, largest standard size 18 lbs.	770	"
Melting pots for pitch, smallest size 12" diameter, 2½" deep, three heats	1 300	"
Melting pots for pitch, largest standard size 15" diameter, 2½" deep, three heats	1 600	"
Melting pots for sealing wax, parafine, smallest size ¼ pint, single heat	80	"
Melting pots for sealing wax, paraffine, largest standard size 5 quarts, three heats	550	"
Melting pots for soft metal (lead alloys), smallest size 4 lbs., three heats	200	"
Melting pots for soft metal (lead alloys), largest standard size 50 lbs., three heats	1 500	"
Milk sterilizers for 8 bottles, three heats	700	"
Milk testing sets, single heat	600	"
Milk warmers for 8 ounce bottles 400 to	500	"
Oil tempering baths, smallest size 9 gallons, with controller 600° F. max. temp.	6 000	"
Oil tempering baths, largest standard size 37 gallons, with controller 600° F. max. temp.	20 000	"
Ovens for baking, roasting, drying, warming, enameling, smallest size 14x14x18", three heats	200	"
Ovens for baking, roasting, drying, warming, enameling, largest standard size, 42x30x67", three heats	10 000	"
Potato cookers, smallest size 5 quarts, three heats	750	"
Potato cookers, largest standard size 10 quarts, three heats	1 000	"
Potato steamers for hotels, smallest size 20 quarts, six heats	3 000	"
Potato steamers for hotels, largest standard size 50 quarts, six heats	4 500	"
Puff irons, smallest size 3x1¼", three heats	155	"
Puff irons, largest standard size 6x3½", three heats	400	"
Ranges for domestic and restaurant use, 2 to 6 persons	4 000	"
Ranges for domestic and restaurant use, 6 to 12 persons	5 500	"
Ranges for domestic and restaurant use, 12 to 20 persons	7 500	"
Sand box heaters for trolley cars, single heat	100	"
Sealing wax heaters, hand tool style, single heat	75	"
Shoe irons, portable, single handle, six heats	100	"
Shoe irons, portable, double handle, six heats	210	"
Shoe relasting irons, portable, single heat	50	"
Shoe warmers, smallest size 4"x1¾"x½", single heat	20	"
Shoe warmers, largest standard size 8"x3"x1", single heat	30	"
Sleeve irons, 3½ lbs., two heats	300	"
Soldering irons, smallest size 10 ounces, single heat	75	"
Soldering irons, largest standard size 4½ lbs., single heat	450	"
Steam sterilizers, small size 5 quarts, three heats	3 500	"
Steam sterilizers, large size 6 quarts, three heats	4 000	"
Sterilizers for surgical and dental instruments, smallest size 8"x3½"x2", three heats	350	"
Sterilizers for surgical and dental instruments, largest standard size, 24"x6"x4", three heats 1 400 to	1 800	"
Sweating blankets, 60"x18", with controller	800	"
Toaster stoves domestic, portable type, single heat 400 to	600	"
Toaster stoves, restaurant type, single heat 1 500 to	3 000	"
Towel dryers, three heats	600	"
Waffle irons, each section, single heat	380	"
Welding machines, smallest sizes	1 000	"
Welding machines, largest sizes	150 000	"

SHOP TESTING OF ELECTRICAL APPARATUS—VII

DIRECT-CURRENT MOTORS—SHUNT AND COMPOUND

MANY of the tests already described for direct-current generators apply equally well to direct-current motors. However, this is true only in the case of shunt and compound-wound machines. Series motors, being adapted for special classes of service for which there is no corresponding type of generator, require their own methods of testing.

Shunt and compound-wound motors are generally divided into three classes, according to the service for which they are intended as follows:

1—Machines designed to operate with full voltage on the field.
2—Machines designed to operate with a rheostat in series with the shunt field to adjust the full-load speed to that desired.
3—Adjustable speed machines, designed to operate at various speeds by shunt field control.

In carrying out tests, the actual service conditions of each type of machine should be approximated as closely as possible. This applies especially to temperature tests. It is evident, for instance, that the heating effect in the case of a motor designed for intermittent service, such as an elevator motor, will be quite different from that of a constant speed machine carrying a steady load.

The data given in this article was obtained from a test of a 25 horse-power, 230 volt, 375 to 1 125 r.p.m. commutating pole, compound-wound motor.

RESISTANCE, CORE LOSS AND SATURATION

The resistance of the armature and fields is determined by the bridge method, as previously described for generators; it is also advisable to check the values obtained by the bridge for the shunt field resistance, by the drop of potential method. The core loss, no-load and full-load saturation are obtained in exactly the same manner as for generators, the motor being run as a generator, as described in the May issue.

TEMPERATURE TESTS

For temperature runs, the motor should either be belted or direct-connected to a generator large enough to carry 100 percent overload on the motor; the generator may then be loaded on a water rheostat or by the loading back method previously described.

Common Requirements for All Shunt and Compound Motors—All machines should be carefully inspected for mechanical faults before being started. The brushes should be set on the neutral and the bearings properly filled with oil. In starting, the shunt field switch should always be closed first. If the ammeter indicates approximately normal field current, the armature circuit may be closed; a starting box or, if none is available, a suitable resistance, such as a rack or water rheostat, should be connected in series with the armature and adjusted so that the motor will start gradually. The shunt field ammeter should be watched closely while the machine is speeding up; if it indicates a decreasing current, the field is connected across the armature starting resistance, and the motor should be shut down immediately; otherwise it may reach a dangerous speed. as the armature resistance is cut out. If the motor is operating satisfactorily, the resistance should be gradually cut out of the armature circuit until the machine has reached normal speed. In the meanwhile, an examination of the oil rings should be made to ascertain that they are revolving and carrying up sufficient oil, and the general operation of both the motor and the generator to be used for load should be carefully observed.

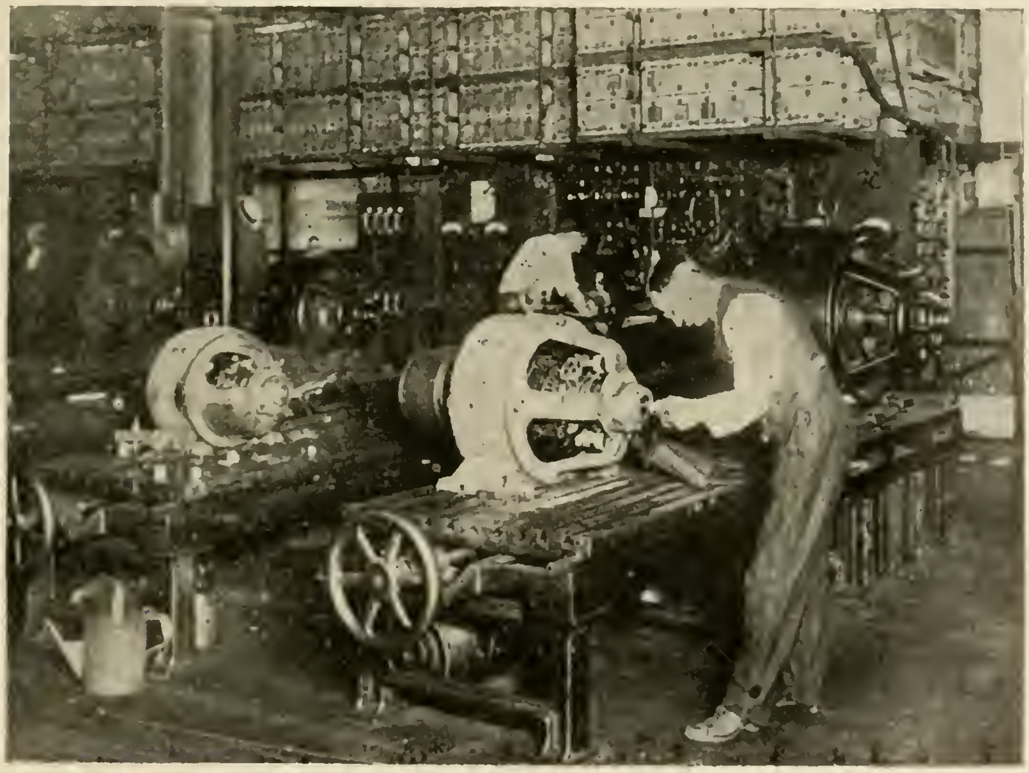

FIG. 1—HEAT RUN ON A 25 HORSE-POWER COMPOUND-WOUND DIRECT-CURRENT MOTOR

The load is now brought up to normal and a reading of speed, line volts and amperes, field current and voltage of each field winding taken. In case it should be necessary to shunt part of the current from the commutating pole winding in order to secure the proper commutation, the amount of current shunted should be noted. The same rule applies to any case where current is shunted from the series coils of a compound machine. In such cases, at the end of the temperature test, readings of voltage drop across the winding in question, both with and without shunt, should also be taken, in order that data may be available for computing more accurately the permanent shunt which is to be supplied with the machine. This is sometimes done by measuring the shunted current directly with an ammeter. The readings of speed, line volts, etc., should be taken every hour in case of continuous runs, and every half-hour if the run is only one or two hours in duration. In fifteen minute runs a reading is taken at the beginning and another at the end of the test. In all cases the rated voltage must be held constant at the terminals, but a variation in the other quantities is permissible. The condition of the commutator should be noted at the beginning and end of the test, and the commutation at the time of each reading. After the field current or speed, as the case may be, has become constant, which usually takes from six to eight hours, depending on the size and type of machine, the motor should be shut down and temperatures taken on the various parts. Hot resistances are also taken at this time, if required. Care should be taken to obtain all temperatures in the shortest time possible, as a machine that has been shut down will cool off very rapidly. The thermometers, waste, and other epuipment should be ready, and the work should be planned out beforehand, so that no time will be lost after shut down. In taking resistances, it is well to take first the winding that tends to cool off the most rapidly, which will usually be either the series or commutating field.

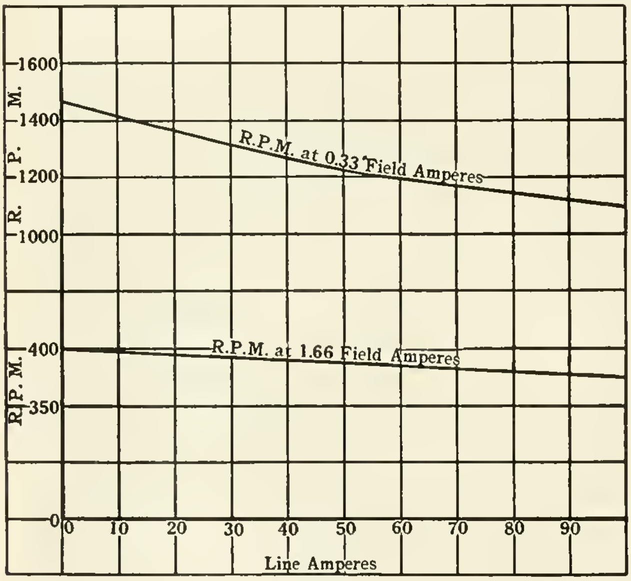

FIG. 2—SPEED REGULATION CURVES

Showing relations between speed and current at maximum and minimum speed ratings.

Special Application for Different Types of Motors—It is usually necessary to vary the temperature runs slightly to suit the different classes of motors. Machines of the first class are operated with normal voltage held constant on the field, and at rated values of armature current and terminal voltage. Under these conditions, a change in speed will occur during the run, due to heating; this change in speed, however, should not exceed ten percent of the full-load speed, based on the speed at the end of the run, and the actual speed at the end of the run should be within four percent of the rated value. On non-commutating pole motors, if the speed does not come within this limit, the proper value may sometimes be obtained by shifting the brushes, but this should never be done at the expense of good commutation.

On machines of the second class, in which the full-load speed is obtained by means of a rheostat in series with the shunt field, the temperature run is made at rated terminal voltage and current, the rated speed being held constant throughout the test by adjusting the rheostat.

For motors of the third class, or adjustable speed motors, the low-speed temperature tests are made with constant voltage on the field, as with machines of the first class, while the high speed test is made with the speed held constant by varying the field, as in the second class.

STABILITY TESTS

The stability of a motor is the measure of its ability to withstand wide fluctuations in load, suddenly applied, without surging of speed or armature current; that is, with sudden change of load a stable motor will inherently adjust itself to the corresponding speed and armature current without oscillation on either side of the final values. The test for stability is made with the motor connected up as in the temperature run, and it is determined for a certain definite load. The field of the motor is first weakened to give the high speed, and the load on the generator is adjusted to obtain the required load on the motor. The load on the generator is then alternately suddenly removed, and switched on. If the motor is unstable, the speed will vary through a wide range, and the line ammeter needle will swing back and forth over the scale. This test should be repeated several times in each direction of rotation, throwing the load on and off each time rapidly.

Instability of a motor is sometimes due to improper placing of the brushes, or to incorrect adjustment of the commutating-field, and care should be taken that such improper conditions do not exist before a stability test is made.

SPEED REGULATION

In general, speed regulation tests of motors are made to determine the relation between speed and load. The motor is either belted or direct-connected to a generator of sufficient capacity to carry 100 percent overload on the motor, as in the temperature run, the generator being loaded in any convenient manner. The speed curve should be taken with a shunt field current equal to that obtained at the end of the continuous temperature run. In many cases, however, the motor is intended for intermittent service, and the time specified for the full-load run is much less than that required for the shunt field current to become constant; in such cases the field current at the end of the specified temperature run should be used for the speed regulation.

TABLE I

Curve Data—Low Speed

Volts	Armature Amperes	Field Amperes	Total Amperes	R. P. M.
230	110	1.66	111.66	373
230	88	1.66	89.66	378
230	67	1.66	68.66	382
230	45	1.66	46.66	387
230	22	1.66	23.66	393
230	2.6	1.66	4.26	399

Curve Data—High Speed

Volts	Armature Amperes	Field Amperes	Total Amperes	R. P. M.
230	112	0.33	112.33	1072
230	90	0.33	90.33	1125
230	67	0.33	67.33	1182
230	45	0.33	45.33	1248
230	22	0.33	22.33	1350
230	6.75	0.33	7.08	1470

For this test the brushes are set on the running position and the motor started, observing the precautions given above. Then for a motor of this size a curve of at least six points should be taken covering loads from zero to 150 percent. Readings of line volts, line amperes, field volts, field amperes and speed are taken for each point, the terminal voltage and shunt field amperes being kept constant throughout the test. Commutation is observed at all points, and at the 50, 100 and 150 percent points brush potential curves are taken as outlined in a previous article. Readings for curve data for the lower and upper limits of speed range are given in Table I. The final relations desired are those between speed and total or line amperes. The latter is, at each point, the sum of armature and field amperes, and is plotted horizontally in the speed-load curves, Fig. 2.

The speed curve of shunt wound motors will usually be nearly a straight line, unless the armature reaction is very high, in which case the speed characteristic will be rising, particularly at the higher loads. With compound-wound motors, however, cumulative compounding gives a drooping, and differential compounding a flat or rising speed characteristic as the load increases.

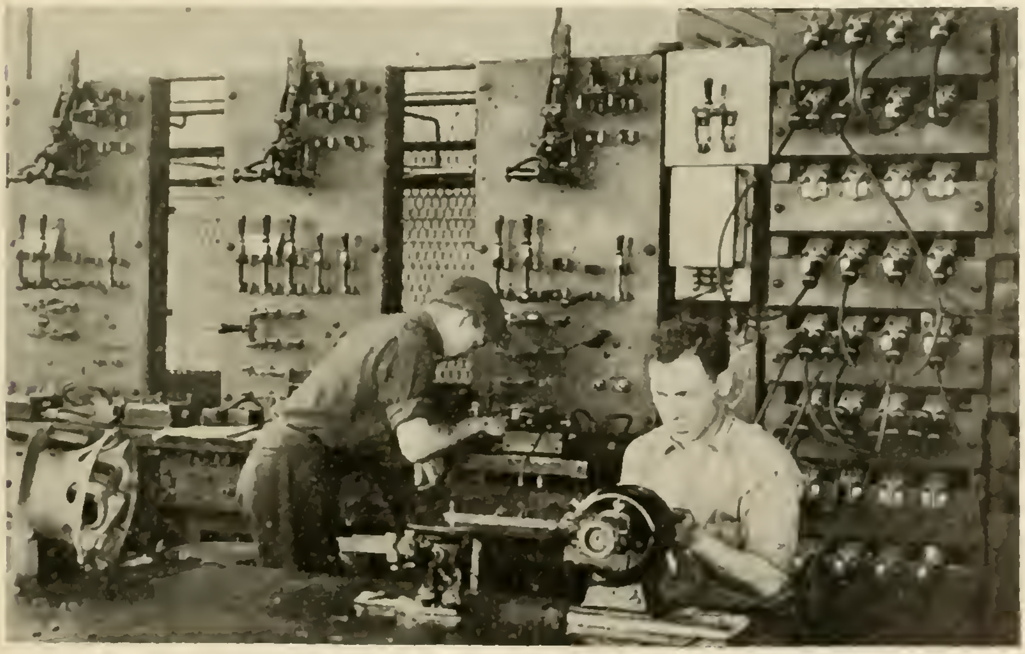

FIG. 3—BRAKE TEST ON SMALL DIRECT-CURRENT MOTOR
Showing method of mounting brake and measuring torque.

If the commutating-pole compensation gives a correct brush curve at low speeds, it will probably over-compensate as the speed increases, resulting in a drooping curve. The voltage drop will also be higher with increased speed, owing to the greater resistance of the brush contact.

SHUNT REGULATION

This is essentially a test for adjustable speed motors to determine the relation between the shunt field current and the motor speed over the rated range of operation.

When the control apparatus is included in the test, its resistance must first be adjusted to give the rated maximum and minimum speeds, and the various intermediate points must be arranged to increase the speed between these limits in equal steps.

Methods of loading are the same as indicated in the speed regulation test, and care should be taken that the speed of the loaded generator does not become excessive, a change of pulley combination being made if necessary. With small motors, the generator method of loading may be replaced by the prony-brake method, as shown in Fig. 3. Care must then be taken also that all conditions are constant before taking a reading.

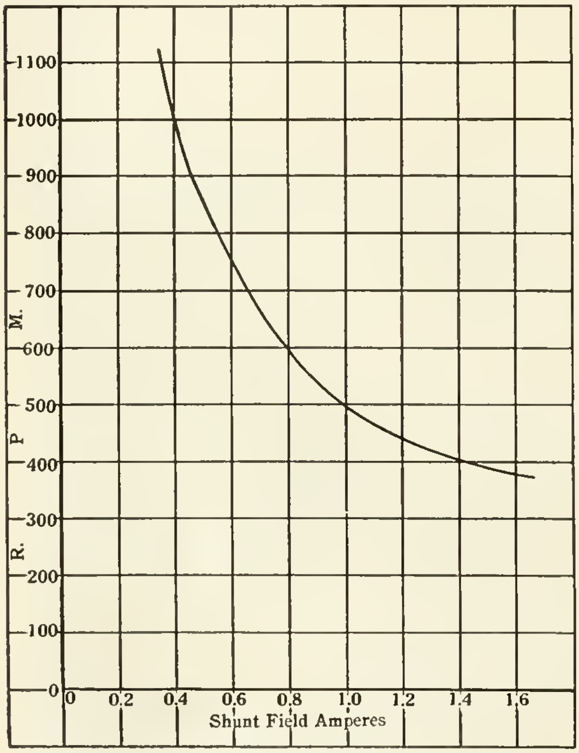

FIG. 4—SHUNT REGULATION CURVE

Giving relation between speed and shunt field strength.

With normal voltage and normal load kept constant at their respective values throughout the test, readings of terminal volts and amperes, shunt field amperes and speed are taken at eight or ten points, covering the range for which the control is set, the points being separated by equal differences in speed, rather than in shunt field current. Commutation is noted at each point.

The results of a typical test on a 25 horse-power motor are given in Table II. The desired curve, shown in Fig. 4, is obtained by plotting speed as ordinates against field amperes as abscissae.

EFFICIENCY BY LOSSES

Instead of measuring the output of a motor directly, efficiency (the ratio of output to input) may be calculated by measuring the total losses of the motor. This can readily be done from the values of core loss, friction and windage, shunt field current, and the resistances of all current carying parts, most of these values having been already obtained in connection with other tests. Loss readings at no load and at every quarter load up to 25 percent overload are sufficient data for this test. All other tests having been taken, efficiency can be calculated directly by this method without further operation of the motor as follows:

E=Terminal volts; rated voltage of the machine.

I_t=Terminal amperes at any desired load.

I_s=Shunt field amperes, as obtained from temperature test or speed regulation.

I=Armature amperes $= I_t - I_s$.

r=Armature resistance hot, or at 60 degrees C.

r_1=Series field resistance hot, or at 60 degrees C.

r_2=Resistance of shunt on series field.

r_3=Resistance of series field with shunt $= \frac{r_1 \times r_2}{r_1 + r_2}$.

r_4=Commutating-field resistance hot, or at 60 degrees C.

r_5=Resistance of shunt on commutating field.

r_6=Resistance of commutating field with shunt $= \frac{r_4 \times r_5}{r_4 + r_5}$.

TABLE II—SHUNT REGULATION

Volts	Armature Amperes	Field Amperes	R. P. M.
230	90	1.66	375
230	90	1.34	418
230	90	1.036	491
230	90	0.84	570
230	90	0.68	668
230	90	0.58	760
230	90	0.504	838
230	90	0.44	930
230	90	0.38	1031
230	90	0.33	1125

B=Volts brush drop $= \frac{I}{20 \times \text{total brush area}} + 1$.

Then R = Armature resistance (r) + series field resistance $(r_1 \text{ or } r_3)$ + commutating-field resistance $(r_4 \text{ or } r_6)$.

The above formula for R must include the running resistance of all windings in series with the armature.

$e = I \times R$ (total drop of all series windings).

(1)—Total induced volts $= E - e - B$.

(2)—Core loss at total induced voltage (1) obtained from core loss curve.

(3)—Shunt field copper loss $= E \times I_s$. This will include the rheostat in the shunt field.

(4)—Copper loss of the armature and the windings in series with it $= (I \times e)$ or $(I^2 \times R)$.

(5)—Brush loss $= (I \times B)$.

(6)—Brush friction, friction and windage.

Total losses = (2) + (3) + (4) + (5) + (6).

Input $= E \times I_t$.

Output = Input — Total losses.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}.$$

It is simpler in this case to calculate efficiency directly from kilowatt values rather than to change over to terms of horse-power in which the motor is rated. Then, efficiency and output being determined, the motor-torque at any point can be determined as follows:

$$T = \frac{Hp \times 5250}{\text{r.p.m.}},$$ where T is the torque in pounds at one foot radius and *r.p.m.* is the speed at a given load *Hp*. The values of torque thus obtained will be slightly high owing to the omission of small load losses in the motor which are not considered in the separate loss method.* The results of a complete calculation for the 25 horse-power motor used in connection with this article are given in Table III.

TABLE III—COMPLETE CALCULATION FOR 25 HORSE-POWER, COMPOUND-WOUND DIRECT-CURRENT MOTOR

Approximate Load, Percent.	0	25	50	75	100	125
Line Amperes ......I_t	5	22	45	67	90	112
Shunt Field Amperes.I_s	1.66	1.66	1.66	1.66	1.66	1.66
Armature Amperes....I	3.34	20.34	43.34	65.34	88.34	110.34
Terminal Volts......E	230.	230.	230.	230.	230.	230.
Arm., Ser. & Com. F. Volts ....e	.4	2.80	5.98	9.0	12.17	15.2
Brush Drop ....B	0.0	1.17	1.36	1.55	1.74	1.93
Total Drop.....e + B	.4	3.97	7.34	10.55	13.91	17.15
Total Induced V.....1	229.6	226.03	222.66	219.45	216.09	212.87
Core Loss 2	430	406	390	375	355	343
Shunt Field Loss....3	381	381	381	381	381	381
Arm., Ser. & Com. F. Loss 4	1.5	57	259	588	1075	1677
Brush Loss 5	0	24	59	108	154	213
Brush Friction	60	60	60	60	60	60
Friction and Wdg.....	120	120	120	120	120	120
Total Losses	992.5	1048	1269	1632	2145	2794
Watts Input	1150	5060	10350	15410	20700	25760
Watts Output	158	4012	9081	13778	18555	22966
Efficiency	13.7	79.3	87.8	89.5	89.6	89.2
HP Input	1.54	6.78	13.86	20.65	27.7	34.5
HP Output	.21	5.38	12.18	18.48	24.9	30.75
Speed (from curve)...	398.	393.	387.	382.	377.	373.
Torque	2.77	71.9	165.2	254.	347.	433.

Brake Tests—Brake tests of any kind are inherently difficult to conduct accurately, so that the more precautions taken when making the test, the more reliable the results will be. The length of the brake arm must be measured horizontally from a perpendicular line through the center of the shaft to the point at which the beam rests on the scales. The tare of the brake arm must be determined before each test; this should be done by supporting the brake beam with its complete equipment horizontally, the one end resting on the scale platform as in operation, the other supported by a knife edge from the point at which the perpendicular through the center line of the shaft intersects the brake arm. The weight shown on the scales under these conditions will be the tare of the brake arm, and to this must be added the weight of any other materials on the scale platform during the test. Good condition of the brake pulley is essential in this test. It must be in good mechanical balance and must run true, as otherwise it will cause the brake arm to vibrate badly, resulting in very unsatisfactory scale readings. The pulley must be kept at a reasonably constant temperature while taking the reading, as a sudden change in temperature will cause a change in load, because of the brake band becoming either tight or loose on the pulley. This can be avoided by keeping the brake pulley cool with a stream of cold water flowing into the pulley to carry off the heat.

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*See in A. I. E. E. Proceedings, paper by Mr. E. M. Olin, July, 1912, and paper by Messrs. Olin and Henderson, February, 1913.

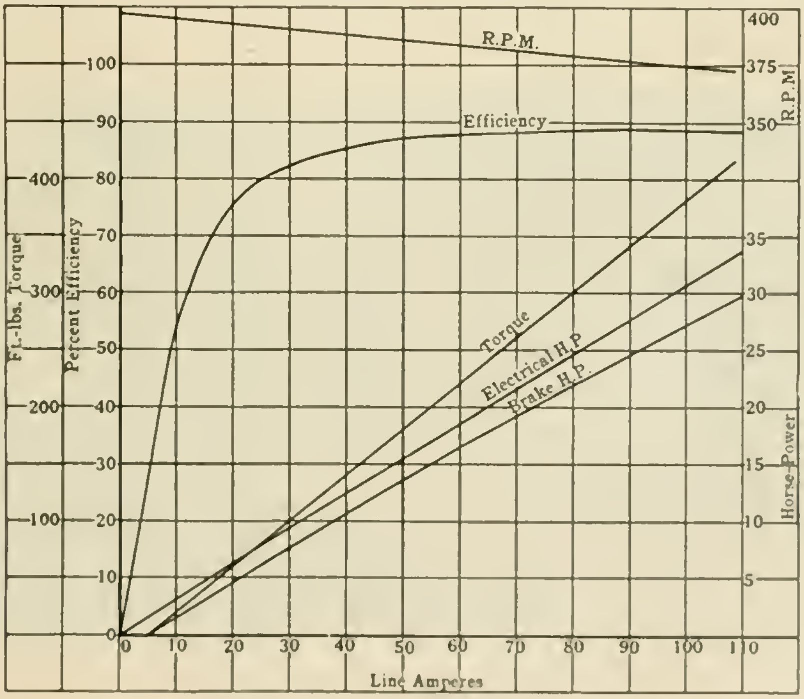

FIG. 5—COMPLETE RESULTS FROM TEST GIVING MOTOR-PERFORMANCE CHARACTERISTICS

The speed and torque curves can be taken separately, the former by belting to a generator, as previously described, and the latter by brake; the two tests are then combined to make the brake test. The only reason for separating the tests is to obtain a better speed curve, due to the more steady load obtained by belting. The same meters should be used in making separate speed and torque tests to be combined for efficiency curves, and the line volts, field amperes and machine adjustments must be the same for each test. Preferably the two curves should be taken at the same location, so that the meters will be kept in the same positions, avoiding changes in local conditions that might affect their accuracy. In all brake tests, the precautions, as given above for brake arm, having been taken and the field connections having been checked as in the speed regulation test, the motor is started, the brake arm meantime being held to avoid accident due to its swinging around in case the motor should happen to start in the wrong direction. After the motor is running correctly, the shunt field current is adjusted to the required value and the no-load reading is taken. From this point the tension on the brake band will adjust the load to the points desired between zero and 125 percent load.* At each point, the desired load having been obtained, the torque must be held constant on the scales and the readings taken when the scales are evenly balanced. In a test offering so many possibilities for inaccuracy several check readings should be taken of the current at each point and the average of these used for the correct reading. A set of readings for a typical test of this nature is given in Table IV. The results of these readings can be most clearly shown by plotting speed and torque curves against line amperes as abscissae, as given in Fig. 5. Then from the curves select speed and torque values at points of even values of current, using values in Table V. The smooth curves having been plotted from the values of speed and torque, brake horse-power can be calculated. This should be

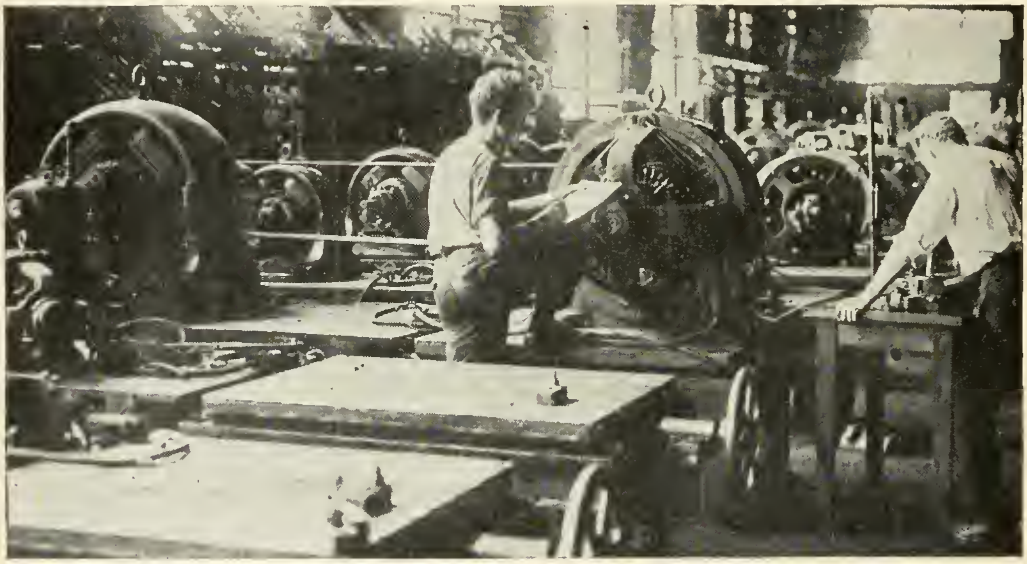

FIG. 6—RUNNING A COMMERCIAL TEST ON A DIRECT-CURRENT COMMUTATING POLE COMPOUND-WOUND MOTOR

plotted also, against line amperes, and since the values are taken from true curves, the brake horse-power curve should pass through all the points. If some of the points are slightly off the curve, efficiency should be calculated from points actually on the curve from the following formula:

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*For methods for securing automatic tension adjustment to maintain a constant load, see the JOURNAL for June, 1912, p. 577, and February, 1907, p. 118.

$$\text{Brake HP} = \frac{\text{Torque} \times \text{R. P. M.}}{5250}$$

$$\text{Electrical HP} = \frac{\text{Line volts} \times \text{line amperes}}{746}$$

$$\text{Efficiency} = \frac{\text{Brake HP}}{\text{Elec. HP}}$$

Values of brake horse-power, electrical horse-power and efficiency, as calculated from this formula and the preceding table, are given in Table VI. The various curves are worked up from the values obtained from preceding curves, instead of actual test values, in order that all curves shall check amongst themselves. All curves are then plotted, with line amperes as abscissae and all other values as ordinates. The results of a complete brake test are given in Fig. 5.

TABLE IV—BRAKE TEST—OBSERVED DATA

Volts	Armature Amperes	Field Amperes	Line Amperes	R. P. M.	Torque
230	107	1.66	108.66	372	415
230	87.2	1.66	88.86	379	339
230	66.5	1.66	68.16	381	255
230	44.3	1.66	45.96	387	166
230	23	1.66	24.66	393	80
230	3.04	1.66	4.70	398	0

TABLE V—BRAKE TEST—DERIVED DATA

Volts	Line Amperes	R. P. M.	Torque
230	110	374	421
230	90	377	343
230	70	381	263
230	50	386	182.5
230	30	394	102.4
230	20	391	62.5
230	10	397	22

COMMERCIAL TESTS

When motors are built in large quantities, or when they have become standardized for given ratings and characteristics, a complete engineering test is not necessary for every machine. Instead, when a few, as typical of a given lot, have been tested thoroughly, the rest are given only such tests as will demonstrate their conformity to the requirements of their particular design. This is known as "commercial" testing, and is usually carried out with reference to limits based on the results of the complete engineering test. In order to introduce an occasional check on this method, however, where a given type of machine is built in very large numbers, a motor is selected from the lot at regular intervals and given a complete test.

The procedure in a typical commercial test is as follows, the motor in this case being a constant speed, commutating pole machine: first, all brushes are properly spaced and ground. They are then replaced by others—especially adapted for finding the neutral position—which are bevelled evenly on each side, leaving only sufficient surface in the center to span a single commutator mica segment. So narrow a brush surface enables speeds to be taken in each direction of rotation without any change in brush contact, which is likely to occur with the regular brushes when new, unless extreme care is taken in grinding and adjusting them.

TABLE VI—DATA FOR EFFICIENCY CURVE

Line Amperes	Brake Hp	Electric Hp	Efficiency
110	29.95	33.9	88.4
90	24.63	27.74	88.7
90	19.07	21.57	88.4
50	13.42	15.42	87.1
30	7.63	9.25	82.5
20	4.69	6.17	76
10	1.665	3.08	54

The motor is then belted up to a generator capable of carrying at least 25 percent motor overload, and all precautions taken as to mechanical operation of both machines. Just before starting a reading of field current should be taken at normal voltage. The motor is then started and the neutral point determined by taking speeds in each direction of rotation at normal full load, as described in a previous article.* Stability is checked at 125 percent load, and at any higher value required, and then complete full-load readings of line volts, line amperes, field volts, field amperes and speed are taken, the motor being checked meanwhile for commutation and noise. A no-load reading with specified field current completes the operating test, and it only remains to make the standard insulation test.

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*The Journal, April, 1913, p. 375.

Commutating Pole Elevator Motors—Elevator motors require characteristic commercial tests, owing to their special operating requirements. They are divided into three classes, depending on the conditions under which they are to operate.

Class I—Motors whose operating speeds are obtained by weakening the field, the field being fully excited only at the time of starting.

Class II—Motors whose shunt field is continually excited whether the motor is operating or not.

Class III—Motors designed for very intermittent duty, such as certain freight elevator service.

The essential information in connection with these motors is that regarding temperature characteristics and accordingly these tests are for the most part temperature runs. Motors of Class I are run for 15 minutes at normal current and voltage, and two-thirds maximum speed rating. With motors of Class II, the armature being held at a stand still, the shunt field is excited for a short time with a current sufficient to increase the field drop by 15 percent, which gives the estimated temperature condition of the field for continuous excitation at normal voltage. The motor is then run for 15 minutes at rated amperes, voltage and speed. Motors of Class III, being for very intermittent duty only, are run for 10 minutes at normal rating.

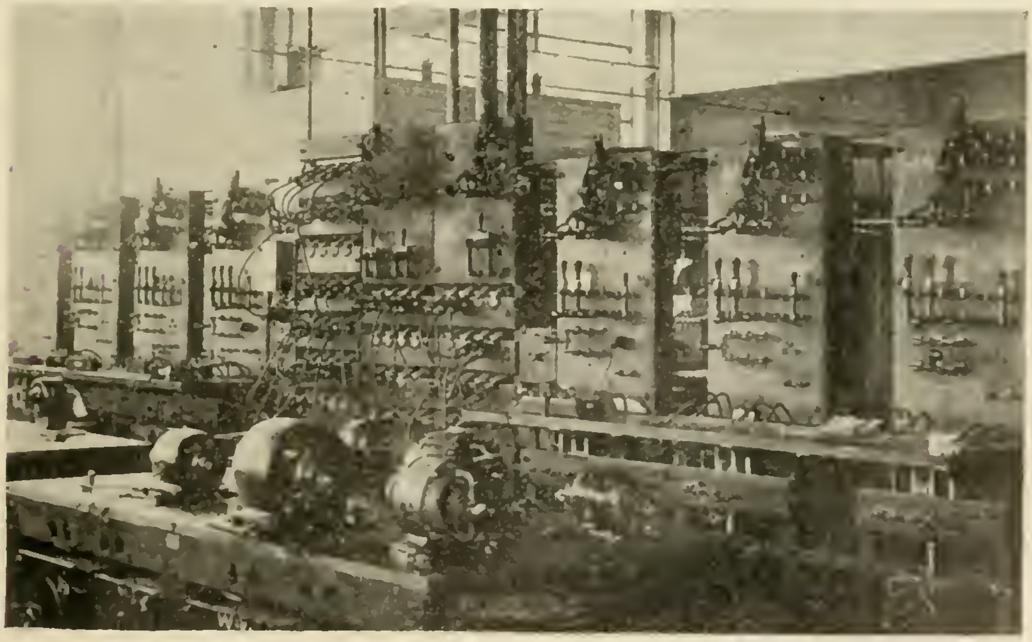

FIG. 7—A SERIES OF PANELS WITH PLUG BOARD USED IN CONNECTION WITH THE TESTING OF SMALL DIRECT-CURRENT MOTORS

At the beginning and end of each test, readings must be taken of armature amperes, armature volts, field amperes, field volts and speed, and the values obtained must check within the limits of the standard machine of the same design on which a complete engineering test has been run. Special care must be taken on shutting down that all temperatures are taken as rapidly as possible, as the high temperature at which these motors operate decreases very rapidly on cessation of load. All temperature tests should be started with the machine cold and not after the completion of any other test that might, to any extent, heat the motor.

With few exceptions the series fields of these motors are for use at the instant of starting only, and so should be cut out of the circuit during the temperature test. However, after its completion, the motor should again be started up with the series winding connected in and a reading of speed taken with the motor operating at normal load, voltage and shunt field current, care being taken that the motor does not operate more than five minutes under this condition as the series field winding is likely to overheat. After completion of the temperature test the motor should be shut down, belt and pulley removed, and again started up, this time running idle, readings being taken of armature amperes, armature volts, field amperes and speed, normal voltage being impressed on the armature and the field current used being that obtained at the end of the temperature test. These readings are sufficient to check any machine with the standard machine of the same design on which a complete engineering test has been made. The commutator should now be cleaned, the shaft polished, and a complete mechanical inspection made. If this is satisfactory, the motor may now be shut down, all wires disconnected, and the test completed by the required over-potential insulation test. For elevator motors of the non-commutating pole type, the test is similar to the above, variations occurring only to meet varying operating conditions.

SPECIAL TESTS FOR DIRECT CURRENT MOTORS

Frequently, for engineering purposes, direct-current motors are subjected to special tests. The more common of these are field form tests and saturation of commutating pole winding, which are carried out in the same manner as given in the previous article under generators.

STROBOSCOPIC METHOD OF MEASURING INDUCTION MOTOR SLIP

C. W. KINCAID

IN measuring the slip of induction motors by the stroboscopic method, a disk with painted sectors, usually black and white for contrast and generally with the same number of black sectors as the motor has poles, is mounted on the shaft of the motor. When this disk is rotated rapidly, the colors on the sectors blend and produce one color. The separate colors can be seen either by rapidly interrupting the light from the disk to the eye or by varying the intensity of the light on the disk. The light from the disk to the eye may be interrupted by looking at the disk through another rotating disk with alternate sectors cut out, Fig. 1, thus allowing any point on the painted disk to be seen only at certain positions of the perforated disk. In this method such a second disk is fastened to the shaft of a synchronous motor placed in such a position that the disk on th induction motor may be seen while looking through th disk on the synchronous motor, which of course runs at a speed directly proportional to the frequency of the supply circuit. When the synchronous motor has the same number of poles as the induction motor, the number of sectors cut out is made the same as the number of black sectors on the painted disk, but not necessarily the same as the number of poles. If the number of poles of the synchronous motor available is not the same as the number of poles of the induction motor, the number of black painted sectors on the induction motor disk and the sectors cut out of the synchronous disk should bear the same relation as the numbers of poles on the two machines.

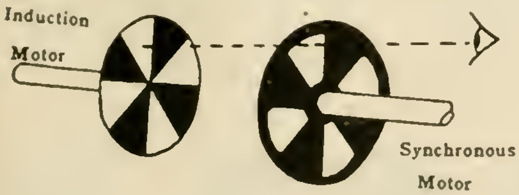

FIG. 1

When both disks are rotating at the same speed, and one is viewed by looking through the other, the painted disk will appear to be standing still. An induction motor usually runs at a lower speed than synchronism, thus causing the segments on the painted disk to appear to be shifting backwards. This shifting has the appearance to the eye of a steady rotation backwards. The number of revolutions the painted disk appears to rotate in a given time multiplied by 100 and divided by the number of revolutions a synchronous motor, having the same number of poles, makes in the same time will give the percent slip of the induction motor.

Instead of the synchronous motor and the perforated disk, a carbon arc lamp, or mercury arc, connected to the same electric circuit as the motor, may be used to illuminate the painted disk, which in this case must have the same number of black sectors as there are poles on the motor. The intensity of light from the arc varies during each alternation approximately with the current, as in Fig. 2, passing from a maximum to a low value when the current passes through zero and becoming a maximum again when the current reaches a maximum value in the other direction. Thus the disk will have a maximum illumination once during each alternation and the disk will be seen better at this time. If the motor is running at synchronous speed, it will move one pole per alternation and, having as many black sectors as poles, one sector will move up to the position of the one next ahead once every alternation. Since the disk is seen best once every alternation, the black sectors will appear in the same position and seem to be standing still. When the motor is running below synchronous speed, the sectors will be brightest when the disk has moved only part of the way from one sector to the next, so that each black sector will be seen shifted a little back of the position the sector ahead occupied at the previous alternation. At the next alternation it has lost twice the distance and appears farther back, and so on in rapid succession, making the disk seem to rotate in a backward direction.

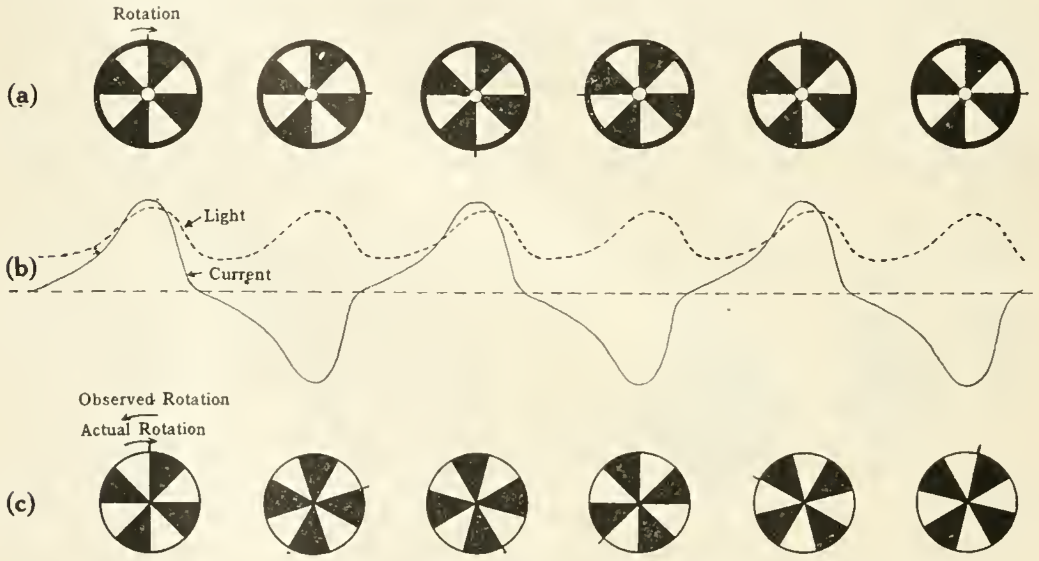

FIG. 2

a—Positions of perforated disk on four-pole synchronous motor at successive alternations or quarter revolutions.

b—Approximate shape of curve of light intensity from arc lamp compared with approximate current curve.

c—Positions of painted disk on induction motor at successive alternations. Black section seems to be displaced counter-clockwise 1/24 of a revolution, or 16 2/3 percent slip.

If a sector appears to be shifted one-tenth of the distance between sectors each alternation, or from one sector position to the next in ten alternations, the slip is one out of ten or ten percent. Since this time and space is too short to be measured and seen, the readings are taken for a minute or longer. The number of revolutions the disk appears to rotate per minute is the actual number of revolutions per minute, that the motor falls below synchronous speed. This number multiplied by 100 and divided by the synchronoous speed gives the percent slip.

For example, assume an eight pole, 60 cycle motor and that the disk seems to move as above. The disk has eight black sectors and seems to move one sector in ten alternations. At 60 cycles there are 7 200 alternations per minute, therefore the disk will seem to move 720 sectors or $\frac{720}{8} = 90$ revolutions per minute. This gives ten percent slip, the synchronous speed being 900 r.p.m. If the frequency is not known, the synchronous speed may be obtained by adding the revolutions slip per minute to the speed of the motor. It is more convenient in this method to use a stop watch to find the time required to make a certain number of revolutions, as only one thing needs to be watched at a time.

For instance:—On a 60 cycle, eight pole motor, it took 20 seconds for the disk to appear to rotate ten revolutions; that is $\left(\frac{60}{20} \times 10 =\right)$ 30 r.p.m., which divided by the synchronous speed $\left(\frac{60 \times 120}{8} =\right)$ 900, gives 3-1/3 percent slip, i. e., $\frac{R_s \times P}{S \times 1.2} =$ percent slip.

Where S = time in seconds to slip the number of revolutions counted.

Rs = Revolutions of disc in time observed.

P = number of poles for which the machine is wound.

This method is more easily applicable on low slips than on high, as when the slip becomes much over 100 per minute, it is difficult to count. Either method, however, can be used to good advantage after the necessary apparatus has been properly arranged and with quite satisfactory results. In the first method, a small synchronous motor may be arranged for regular use in this way, and it is then only necessary to put a painted sector disk on the shaft of the induction motor under test.

APPLICATION OF TEMPERATURE RELAYS

BENJAMIN H. SMITH

IN recent sub-station designs, considerable attention has been paid to the elimination of the human factor and the production of a practically self-operating plant. This has been accomplished in the case of electric distribution systems in numerous instances, with entirely satisfactory results. Efforts have been made to extend this principle to the more purely mechanical features of substation apparatus, a good example of which is afforded by an installation recently made for the city water supply of Memphis, Tenn.

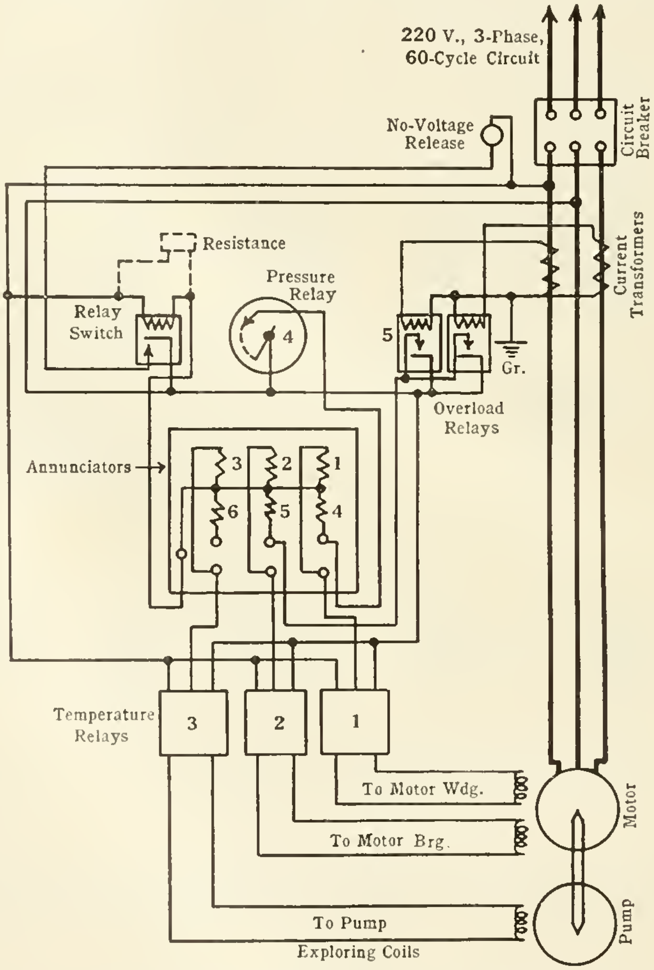

FIG. I—DIAGRAM OF CONNECTIONS, SHOWING COMPLETE LAYOUT OF PROTECTIVE APPARATUS FOR A SINGLE PUMPING OUTFIT

Part of the water for the city is derived from a number of artesian well pumping stations. Each of these stations consists of a 100 horse-power, 60 cycle, three-phase, 220 volt induction motor, direct-connected to a centrifugal pump, with the necessary switches, valves, etc. In the past it has been necessary to have an attendant at each station to be on the look-out for overload, overheating and high water pressure. The expense for attendance has been a considerable item and, in order to reduce the cost of up-keep, a form of apparatus was installed which shuts down the motor automatically in case of over-heating, over-load or excessive water pressure. The latter two requirements were easily met with standard devices, but a special design was necessary to provide protection against over-heating.

The general arrangement of the apparatus for this purpose is shown in Fig. 1, which is typical of the installations in the various pumping stations. Overloads are provided for by two overload relays operating through current transformers, and a water pressure relay designed to trip the circuit breaker when the water pressure reaches 75 pounds, takes care of accident to the water mains. The function of the temperature relay is to guard against overheating in those parts of the apparatus in which it is most likely to occur. All relays operate through a relay switch which is adjusted to open the no-voltage release circuit in case any of the relay contacts should close, due to abnormal conditions in their respective circuits. To facilitate the locating of the difficulty a system of annunciators placed in the various circuits indicates which relay has operated.

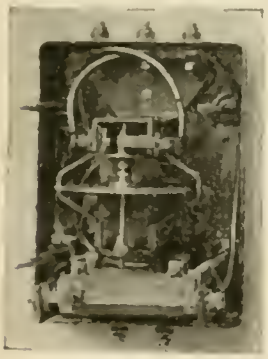

FIG. 2—INTERNAL CONSTRUCTION OF TEMPERATURE RELAY, INDICATING SIMILARITY TO INDUCTION TYPE METER

Three temperature relays are provided, one for the motor winding and one each for the bearings of the motor and of the pump. These relays consist in general of an aluminum disc pivoted to rotate between two coils of the driving magnet in a manner similar to that employed in the construction of induction type meters, as shown in Fig. 2. Rotation of the disc closes a contact and operates the circuit breaker through the relay switch and no-voltage release. The general arrangement of the relay circuit follows the plan of a Wheatstone Bridge as indicated in Fig. 3, but instead of being operated from a battery in the manner of the ordinary resistance bridge, the 220 volt, 60 cycle line is taken as the source of power. The main winding of the magnetic circuit in the relay proper forms two sides of the bridge, a third, consisting of approximately 500 ohms of adjustable resistance with practically zero temperature coefficient. The fourth side of the bridge is formed by an "exploring coil," which is arranged on the bearings of the motor in such a way that its temperature is completely controlled by that of the part to be protected. This exploring coil is of about 500 ohms resistance, and consists of No. 36 copper wire wound around some eight feet of rope, arranged so as to permit the placing of the coil in the most advantageous position to be affected by the changes in temperature of the motor or bearings. The coil itself is thoroughly insulated from the apparatus around which it is wrapped by insulating tape as shown in Fig. 4. Since copper has a temperature coefficient of about 0.4 of one percent per degree, a rise of 50 degrees C in temperature will increase the resistance of the coil to some 600 ohms. In an ordinary Wheatstone bridge such unbalancing of the resistance would cause considerable current to flow through the galvanometer coils; in this case the galvanometers are replaced by the torque producing coils of the temperature relay and a rise of 50 degrees will produce a torque of approximately five gram-centimeters on the aluminum disc.

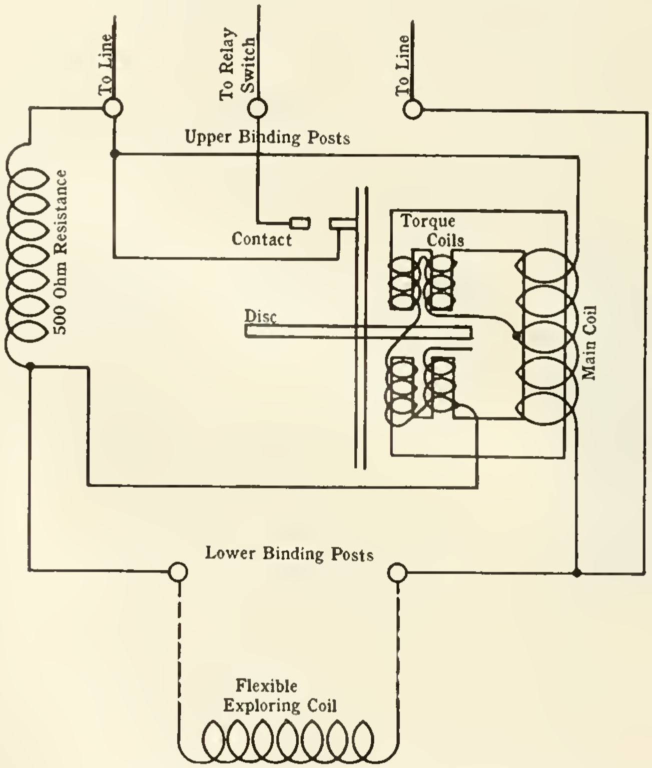

FIG. 3—SCHEMATIC DIAGRAM, SHOWING INTERNAL CONNECTIONS AND PRINCIPLE OF OPERATION OF TEMPERATURE RELAY

By means of an adjustable resistance and a retarding spring acting on the disc, the relay may be set to operate at any given temperature within a wide range. The adjustment is so made that at ordinary temperatures an approximate balance will exist between the two sides of the bridge, and practically no current will flow through the torque coils. As the temperature increases, however, and with it the resistance of the exploring coil, current will commence to flow through the torque coils, but the retarding spring will prevent rotation of the disc far enough to close the contacts, until the temperature reaches the point for which the relay has been adjusted. The current through the magnetizing coils will then produce a torque sufficient to overcome the effect of the spring and the relay will operate, whereupon the circuit breaker opens. Adjustment is usually made so that the relay will stop the motor when the temperature of bearing or winding reaches 75 or 80 degrees C.

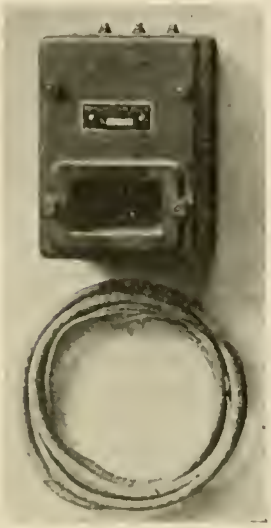

FIG. 4—TEMPERATURE RELAY WITH FLEXIBLE EXPLORING COIL.

Temperature relays such as these afford very simple protection in locations where over-heating of apparatus is liable to occur. The design of the exploring coil is such that it can be fitted to any fixture regardless of shape or location, while the relays themselves may be mounted at some distance in a position where they may be readily inspected.

THE JOURNAL QUESTION BOX

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926—Record of Oscillating Currents—I am anxious to obtain some definite information regarding the obtaining of a photographic record of the oscillating currents which occur in a condenser discharge having resistance and inductance in circuit. The frequency of these oscillations is of a high order and the ordinary oscillograph will not indicate them of course. The Braun Tube method and one originated by Ruhmer using the Geissler tube having electrodes of axially arranged wires separated at the center by a thin mica sheet, and a rotating mirror seem both to have something more nearly what I want However I cannot find data of a definite nature on either. What can be shown by both or other methods in the way of indicating the wave form and the intensities of currents?

J. G. Z. (WISCONSIN)

Photographs of the discharge spark itself can be made easily at high frequencies by the revolving mirror method, but to obtain delineation of the current is of course more difficult, although possible at lower limits. In all methods the constants of the discharge circuit are made sufficiently large to create a frequency low enough to permit good recording. For fairly good quantitative work, up to about 1 500 cycles per second, the oscillograph can be used, either by throwing the beam from the element mirror directly upon a film moving at high speed (fifteen to twenty feet per second), or by making a repetitive process of the discharge. The Duddell short period element is best suited, and exceptional care with details, such as clean mirrors, clear oil, etc., are necessary. In the first method the wave cannot be spread out much (perhaps one-eighth inch per cycle) although the record can later be enlarged, and special pains must be taken to secure good light, sunlight properly directed and focused being better than the usual arc. In the second method, one practice, due to Prof. Fleming, has upon the shaft of an alternator supplying current to the synchronous motor which drives the oscillograph reflecting mirror, a contactor which alternately charges and discharges the condenser, synchronously with the reflecting mirror. Details of this contactor are given in Fleming's "Electric Wave Telegraphy," p. 29. The cathode ray tube methods are more troublesome to operate and not so suitable for ordinary quantitative work, but are necessary for the very high frequencies. A good general description of these is found in the above Fleming reference, and more detailed deferences are as follows: Prof. F. Braun—Wied. Ann. der Physik, 1897—Vol. 60, p. 552; Prof. F. Braun—Ann. der Yhysik, 1902—Vol. 9, p. 497; Dr. W. Mausergh Varley, Phil. Mag., 1902—Ser. 6, Vol. 3, p. 500; Dr. W. Mausergh Varley, Electrician, 1905—Vol. 55, p. 335. Mr. Robert Rankin, "The Kathode Ray Oscillograph," THE ELECTRIC JOURNAL, Vol. II., p. 620, Oct., 1905.

A. F. V. D.

927—Current in Wound Rotors—Please give formulæ for computing rotor current in wound rotors. 1—When Y-connected both field and armature. 2—When delta-connected in field and Y in armature. 3—When Y-connected in field and delta in armature. 4—When delta-connected in both field and armature.

H. G. (ONTAIRO)

The most convenient method of calculating the secondary current of a wound rotor induction motor is to calculate first the secondary voltage between rings, when the rotor is stationary with rings open, and normal voltage impressed on the primary, in which condition the action of the motor is the same as that of a polyphase transformer. This open circuit voltage between rings of a motor connected three phase in both primary and secondary may be calculated from the formulæ:—

$$V_2 = \frac{V_1 \times T_2 \times C_2 \times K}{T_1 \times C_1}, \text{ where,}$$

V_2 = secondary volts between rings.
V_1 = primary volts between rings.
T_2 and T_1 = effective series turns in secondary and primary respectively

$$= \frac{\text{turns per coil} \times \text{No. of coils}}{\text{No. of parallels in connection.}}$$

C_2 and C_1 = chord factor of secondary and primary windings respectively = sine (90° × percent pitch of coil). For delta primary and secondary, $K = 1/1 = 1$. For star primary and secondary, $K = \sqrt{3}/\sqrt{3} = 1$. For delta secondary and star primary, $K = 1/\sqrt{3} = 0.577$. For star secondary and delta primary, $K = \sqrt{3}/1 = 1.73$. Since at synchronous speed the rotation of the secondary conductors produces the same rate of change of primary flux through the secondary coils, as is produced by the alternations of the primary flux at stand-still, the voltage as calculated above also represents the counter e.m.f. generated in the secondary winding at synchronous speed. This counter e.m.f. varies directly with the speed, and for any output is equal to V_2 (1—s) where *s* equals percent slip at this output. Since, for an induction motor, the same as for a direct-current motor, the output in watts is equal to the product of the counter voltage and the total armature current. the amperes per ring of a three-phase secondary for a given output are equal to

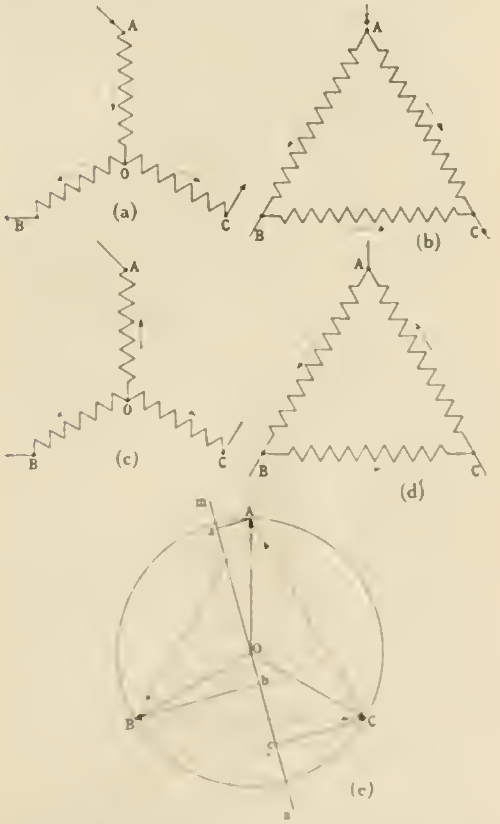
$$\frac{746 \times \text{hp output}}{\text{counter voltage} \times \sqrt{3}}$$

This is neglecting the phase displacement between the rotor voltage and current, which displacement is negligible at normal speeds. Then substituting the value of the counter e.m.f. as found above, the amperes per ring for a given output will be equal to

$$\frac{746 \times \text{hp output}}{V_2 \times (1-s) \times \sqrt{3}}.$$

This neglects several minor factors, which affect the rotor current and voltage, but for all practical cases the value found as above is sufficiently accurate. O. C. S.

928—Positive Direction in a Vector Diagram—In writing the vectorial equations in accordance with Kirchhoff's laws it is necessary to begin with an assumption that the direction of currents or voltages is as shown in Figs. 928 (c) and (d). The direction may also be assumed exactly oposite to that shown, but it is always taken as either all towards the point *O* or all away from the point in case of star connection, and also as acting clockwise or counter-clockwise in the case of delta connection. These directions are usually referred to as positive directions. Now, at some instant the actual directions of either the currents or voltages in star or delta connected devices are as shown in Figs. 928 (a) and (b). At some other instant these directions may be different but they are never all towards nor all away from the point *o* of the star connection and never all clockwise nor counter-



FIGS. 928 (a), (b), (c), (d) AND (e)

clockwise in the case of the delta connection. Will you kindly explain what is meant by the positive direction of an alternating quantity and for what reasons these directions must be used in connection with vector diagrams and vectorial equations instead of the actual directions as shown in Figs 928 (a) and (b) E. J..H. (PENNA.)

Evidently you are confusing the direction of current flow in a scheme of connections with the direction of the vectors in a vector diagram. Thus, in the vector diagram, Fig. 928 (e), the spacing of the vectors *OA, OB,* and *OC,* represents the time or phase relations of the currents flowing in phases *A, B* and *C,* and their length, the maximum or peak value of the current wave. The fact that the vectors all point out from the center has nothing to do with the direction of instantaneous current flow, but indicates only that the peaks are 120 electrical degrees apart. If, for instance, the arrow on *O A* pointed in, it would indicate that the phase difference between *B* and *A,* and *A* and *C* was only 60 degrees. The direction of current flow in windings, such as in Fig. 928 (a), at any given instant is determined from the projection of the vector on a line through *O,* such as *m n,* representing by its angular position the instant desired. This applies to either the star connection as shown by the full lines, or the delta, as shown dotted, the projections being lettered with small letters corresponding to those of the phases. The arrows in the diagrams, Figs. 928 (c) and (d), drawn as a basis for writing vecetorial equations according to Kirchoff's laws, do not represent instantaneous values of current flow at all. They represent positive directions of flow. Thus, when the instantaneous values of flow correspond to Fig. 928 (a), it means that the current in *A* is negative in direction, while that in *B* and *C* is positive. Ordinarily, the positive direction is assumed to be away from a generator and toward a transformer or motor for star connection, and counterclockwise in a delta mesh, although this is not at all necessary. Either direction can be assumed positive, provided the assumptions, once made, are consistently followed. It is necessary to assume some direction as positive in order to determine correctly whether the algebraic signs of the equations should be positive or negative. C. R. R.

929—(a) Referring to switchboard diagram, p. 165, February, 1913 issue, is it correct to represent a straight connection from 2 400 volt feeder to ammeter receptacle? (b) Kindly explain reason for grounding middle point. (c) What is the function of the equalizer resistance connected across the generator field switch, and what is it made of? (d) Are the three point rheostats connected between the Tirrill regulator and the exciter shunt fields, the resistances that are short-circuited by the regulator in the performance of its function? If so, how is it accomplished with the connections shown? G. S. W. (ARIZ.)

(a) A current transformer should have been included in the connection of the ammeter to the leads shown on panel No. 3. (b) The middle point is always grounded on both current and potential transformers, to reduce the possibility of high voltage on the secondary or instrument wiring, due to a breakdown of insulation or any other cause. (c) The word equalizer belongs with the adjacent rheostat not with the field discharge resistance. The function of the latter is to permit opening the field circuit when disconnecting the field, thereby preventing a dangerous rise in voltage which might injure the field. It is usually wound with iron or german silver on the usual resistance supporting devices. (d) The diagram in Fig. 929 (a) shows a simplified connection for this case. The three point rheostat shown in the original arrangement is the exciter field rheo-

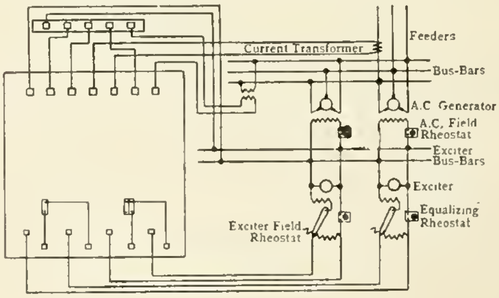


FIG. 929 (a)

stat. It will be noted in Fig. 929 (a) that there are four leads to this rheostat, but two of these go to the same point, and hence one of them was omitted for simplicity in the diagram on p. 165. C. H. S.

930—**High Tension Alternator**—It is proposed to transmit 3 000 kilowatts at 15 000 volts, three-phase. Would it not be more economical to purchase generators wound for this potential than to install 2 200-volt generators and step-up transformers? Granting the former scheme more economical than the latter, would the extra protection afforded the generators (2 000 kw) by use of the latter be sufficient to warrant its adoption?

E. B. (PHILIPINE ISLANDS)

It is possible to wind a 2 000 k.v.a generator for 15 000 volts, if the speed is not too low. It is not desirable, however, and the use of lowering transformers is strongly recommended for the additional insulation protection they afford. It is impossible to state whether the low voltage generator and transformers would be more costly than the high voltage generator without knowing the speed. For intermediate and high speeds the cost would probably be in favor of the high voltage generator, but in spite of this the low voltage generator is recommended. F. D. N.

931—**Type of Motor**—It is proposed to install a three-phase, 250-volt, 50-cycle, 730 r.p.m. induction motor with squirrel-cage rotor and auto-transformer starter. This would be belted to 105 feet of 3 inch existing shafting to run at 180 r.p.m. which has 24 belts and pulleys. The belts before starting are put to loose pulleys, which vary from 40 to 10 inches diameter, chiefly the latter. The full load would be about 35 horsepower when at full speed. Before installing, it is desired to make mechanical tests to know (a) the times full-load torque required on the motor, and be sure of starting; (b) the kind of squirrel-cage winding on motor; (c) how the power-factor and efficiency will be affected. A wound rotor with slip rings cannot be used and it is desired to keep down the line amperes as low as possible.

F. V. (ENGLAND)

(a) To determine the starting torque fasten a lever to one of the fixed pulleys on the shaft, and hang weights on the end until the shaft starts. The product of the weight in pounds into the length of the lever arm from center of shaft in feet will equal the foot-pounds torque. Before doing this the shaft should be belted to another pulley so as to introduce the bearing friction caused by the side pull from the motor belt. (b) and (c) For details as to type of motor see article by Mr. R. E. Hellmund on "Squirrel-Cage Induction Motors with High Resistance Secondaries," in the JOURNAL for November, 1910, p. 870, which deals with the characteristics of different types of squirrel-cage motors.

A. M. D.

932—**Weston Millivolt Shunt**—Are Weston millivolt meters with shunts all designed with approximately the same internal resistance and with the same millivolt drop on the shunt at full load? Thus with a meter and shunt for 1.5, 15 and 150 amperes and scale reading 150 divisions is there any way of finding what the instrument needs in true millivolts?

G. T. S. (VANCOUVER, B. C.)

Weston switchboard shunts are all adjusted to have a drop of 50 millivolts at full load between their potential terminals. The indicating instruments used in connection with the shunts have a drop of 50 millivolts at the terminals of their leads, for full scale deflection. All such instruments have approximately the same resistance. Weston portable ammeters have either 50 millivolts or 100 milli-volts drop according to the type of instrument. The portable ammeters with detachable portable shunts known as Model 1, all are adjusted to have a drop of 100 millivolts at the terminals of their leads for full scale deflection, and are compensated for errors due to changes in temperature. Old instruments of this model were adjusted to shunts having approximately 250 millivolts drop. W. N. C.

933—**High Potential on Cable Sheath**—We have connected with our plant a 6600-volt, three-phase transmission line. The lead sheath which contains the three wires for a short distance recently became charged to a high potential. The following day one of the 6 600-volt wires was discovered on the ground. When it was replaced, no further trouble was experienced with the lead sheath, which is not grounded. Please explain how the grounded wire caused the sheath to be charged. Was it condenser effect?

R. J. L. (PENNA.)

Unless the lead sheath is in actual contact with one of the wires, it would normally assume a potential equi-distant between the wires, corresponding to that of the neutral of the system, due to a combination of leakage and capacity effect. In this case there would be a potential of 3 800 volts between the lead sheath and each of the wires. When one of the wires became grounded, if the sheath is not grounded in any way, it would be raised to a potential approaching 3 800 volts above ground. To prevent a recurrence of this trouble, we would suggest that the lead sheath be thoroughly grounded.

C. R.R.

934—**Wave Form Distortion**—Will pure capacity or inductance in a circuit without the presence of iron serve to distort the wave form of e.m.f.? In other words what tends to produce distortion of the voltage wave?

H. R. S. (PENNA.)

The only effect that capacity or inductance can have upon the voltage wave form of a system or a generator is the indirect one which is caused by the circulation of armature currents through these generators and the effect upon the wave form caused by the armature reaction of these currents. In general it may be stated that the tendency of a given higher harmonic current in the armature of a generator is such as to tend to eliminate that particular harmonic. The foregoing refers to the e.m.f. wave forms and not to the current wave forms. The curfent wave form which is caused by a given e.m.f. wave form will have its distortion decreased when passing through a pure inductance and exaggerated when passing through a pure capacity. P. M. L.

935—**Disconnecting Alternators from Circuit**—On disconnecting a three-phase alternator from the bus-bars, should the exciting current be lowered or kept balanced with that of the other alternator, and why? J. B. (ONTARIO)

It is impossible to reduce the load on an alternating-current generator, which is operating in parallel with other alternators, by reducing the field strength, as is done with direct-current generators. The only way to reduce the power output is to reduce the power which is being delivered to the generator by the prime mover. The best way to cut the alternator out of service is to first decrease the driving power until it is just sufficient to drive the generator without load. If driving power is reduced a little too much, a large circulating current flows through the armature, and in order to avoid breaking a large current, the field should be adjusted so that the armature current is at a minimum. Open first the main switch, then the field switch, and then shut down the prime mover. Care should be exercised not to open the field switch before the main switch is open, as this will cause a heavy surge of current to flow through the armature. R. K.

936—**Formulae for Reactance**—Please show the development of the formulae for inductive reactance and susceptance in three-phase circuits for wires in one plane; at the vertices of an equilateral triangle; and at the vertices of an isosceles triangle?

R. A. C. (OHIO)

The development of these formulae is rather long for publication in the Question Box. It will be found in a book recently published on "Transmission Line Formulae," by Mr. H. B. Dwight. Price, $2.00. C. F.

937—**Charging Alternator from Two-phase to Three-phase**—It is desired to change a 200 kilowatt, 60-cycle, two-phase, 2 300-volt, 720 r.p.m., 10- pole, revolving field alternator to three-phase, 575-volts, other conditions remaining the same. There are 120 coils on the stator (60 in series per phase). How will the change affect the characteristics of the machine. Will the efficiency and the capacity be decreased? E. S. (ONTARIO)

If the machine has a two coil per slot diamond type winding it may be reconnected for 575 volts, three-phase, and will operate practically the same magnetically. In this case the regulation and field heating will be improved, due to the superiority of a three-phase open circuit armature winding over a two-phase open circuit armature winding. The efficiency will remain the same. If it has a one coil per slot concentric winding, it would have to be re-wound with new coils and could, as before, be worked the same magnetically. With the new winding the regulation and field heating would be bettered as above. Also the efficiency and armature copper heating would be improved owing to the greater cross-section of armature copper that could be used on account of the smaller insulation. R. K.

938—Values of Secondary Voltage and Current of Three-Phase Slip Ring Induction Motors—In connection with some calculations, I wish to obtain exact values for the secondary voltage and current of three-phase slip ring induction motors ranging in capacity from 1 to 100 hp. M. D. C. (OHIO)

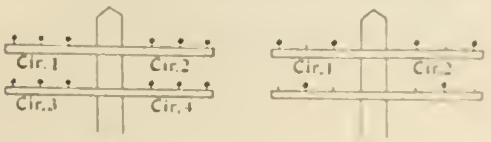
In order to attain the cheapest and best operating controller, a given size of motor requires a certain secondary voltage and amperage. The smaller the motor, the lower should be the secondary voltage, and vice versa. For instance, in the case of a five horse-power motor, a secondary voltage of 80 volts is quite suitable, while for a 100 horse-power motor the secondary voltage should be about 400 volts. While a list of data covering this information for consecutive standard sizes of induction motors throughout the range mentioned is not available, the values may be calculated by means of the methods given in Nos. 927, this issue, 740 May, 1912, and 574, July, 1911. Note also 326, Nov., 1909. H. C. S.

939—Self and Mutual Inductance—Two coils *A* and *B* are wound uniformly upon the same magnetic circuit, one over the other. The self-inductance of *A* is three henries and the self-inductance of *B* is five henries. Assuming the permeability of the magnetic circuit to be constant, how can I determine the total inductance of *A* and *B* when connected in series, (a) so that their magnetic fields are in the same direction; (b) so that their magnetic fields are in opposite directions; (c) What is the mutual inductance of *A* and *B?* T. F. (MASS.)

(a) The combined inductance of the two coils in series equals L_1+L_2+2M where L_1 equals the inductance of one coil, L_2 the inductance of the second coil, and *M* the mutual inductance; (b) The inductance of the two coils in series, with their magnetic fields in opposite direction, is L_1+L_2-2M; (c) The mutual inductance *M* depends upon the magnetic leakage. If the magnetic density is well below saturation, and the magnetic circuit designed with due regard to prevention of leakage, this may be neglected without great error. *M* is then equal to $\sqrt{L_1 \times L_2}$. This is the limiting value. If the leakage is great enough to effect the problem, *M* will be less than given by the formula. C. F.

940—Arrangement of Three-Phase Conductors—Will the arrangement shown in Fig. 940 (a) work without serious inductive effect on a three-phase, 25-cycle, 440-volt line, 400 to 600 feet long or should the second arrangement be used? S. B. F. (PENNA.)

Since the size of wire and amount of current carried is not given it is impossible to give any exact answer to this question. In general the reactance of a circuit in which the wires are all in a row is approximately four percent greater than when the wires are arranged in the form of an equilateral triangle with the same spacings. With the arrangements shown in Fig. 940 (b), however, the spacing of the wires is liable to be so much greater than with the arrangements shown in Fig. 940 (a) that the inductance will very probably be higher. Unless the current and size of wire are very great the inductance will be negligible with either arrangement for a distance as short as 600 feet. C. R. R.



(a) (b)

FIG. 940 (a) AND (b)

941—Three-Phase Transformer Connections—Will the connections indicated in Fig. 941 (a), using two standard 6 600 volt transformers, give a balanced three-phase circuit and what percent of the full transformer capacity can I get from this combination? Is there any connection by which I can obtain a two-phase current by the use of two 6 600 volt transformers, primary voltage, three-phase, 11 000 volts? What results would be obtained by using the combination shown in Fig. 941 (a) using two 6 600 volt transformers, primary voltage 11 000?

H. J. V. (CALIF.)

Two standard 6 600 volt single-phase transformers, connected as shown in Fig. 941 (a), will give a fairly well balanced three-phase circuit provided the neutral point of the apparatus supplying the line is grounded so that the ground forms the equivalent of a neutral ground wire of the three-phase line. The grounds must be good ones and in a country where the ground forms a fairly good conductor; otherwise the connection will not work. The capacity of transformers connected in this way when delivering three-phase current is 87 percent of the single-phase rating. If the neutral of the three-phase system is not grounded, the connection shown in Fig. 941 (a) will give only a three-wire single-phase circuit with 11 000 volts across the outside mains of the primary and 366 volts across the outside mains of the secondary. (b) Two 6 600 volt single-phase transformers cannot be connected to an 11 000 volt three-phase circuit in order to obtain two-phase. This can be done with three transformers in the manner explained in No. 922, June, '13. (c) Reversing the primary of one of the transformers, as in Fig. 941 (b), will simply distort the phase relations of the transformers, if the neutral of the system is grounded. The angles between the sides of a closed delta will be 120, 30 and 30 degrees instead of each being 60 degrees. This will give 220 volts on two phases of the secondary and 380 volts across the third phase. With the neutral of the primary system ungrounded, the result will be a single-phase, three-wire system as in (a), except that the polarity will be reversed. There will thus be 183 volts from each outside to neutral, but zero voltage between the outsire mains.

W. M. M.

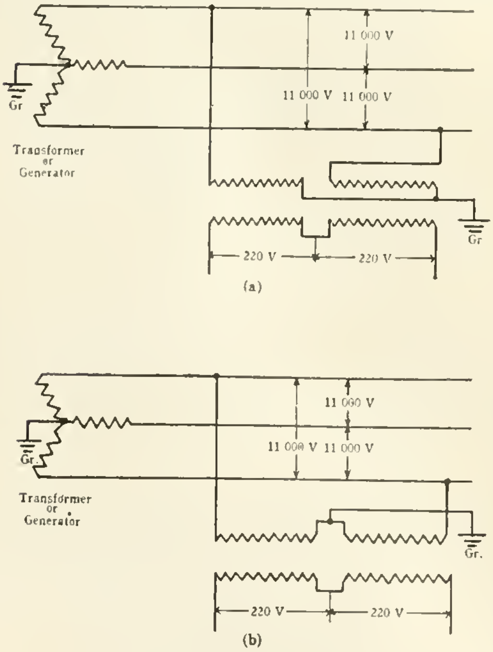


FIG. 941 (a) AND (b)

942—Tirrill Regulator—(a). In connection with a Tirrill regulator is there any reason why one of the exciter rheostats should be divided into two parts, and each part short-circuited by a separate pair of contacts. (b) Is it correct to operate three exciters on a Tirrill regulator having three sets of short-circuiting contacts?

C. W. F. (OHIO)

(a) Yes, if the field discharge is too great for one pair of contacts. On account of the characteristics of different exciters, there can be no definite rule given for the determination of the number of relays or pairs of contacts required for all exciters. Roughly, for 125 volt exciters, a relay or a pair of contacts will be required for each four amperes, shunt field current being taken at 140 volts full load. (b) Yes, provided one relay is of ample capacity for each exciter. See Instruction Book on Tirrill Regulators—type TA—Form F and K, under heading of "Adjustments — Generator and Exciter Field Rheostats." A. A. T.

7/2/14

PERSONALS

Mr. W. W. Coleman, of the Union Switch & Signal Company, Swissvale, Pa., has recently been appointed sales engineer for the Edison Storage Battery Company, Orange, N. J., where he will specialize on signal work.

Mr. T. P. Pinckard, formerly new business manager of the Peoria Gas & Electric Company, is now secretary of the Dominion Traction & Lighting Company of Windsor, Ontario. A number of years ago Mr. Pinckard took the engineering apprenticeship course with the Westinghouse Electric & Mfg. Company and later was in their sales department.

Mr. C. A. Coffin, who has been president of the General Electric Company since its organization, has resigned and has been elected chairman of the board of directors of the company. Mr. E. W. Rice, Jr., senior vice president, has been selected to succeed Mr. Coffin.

Mr. Raymond J. O'Brien, formerly of the railway engineering department of the Westinghouse Electric & Mfg. Company, has accepted a position with Gibbs & Hill, of New York City.

Mr. B. J. Fernald, of the Pittsburgh office of the General Electric Company, has resigned to become sales manager for the Best Mfg. Company, of Pittsburgh.

Mr. S. Leefschetz, who was an engineering apprentice with the Westinghouse Electric & Mfg. Company about six years ago, and has been teaching mathematics in the University of Nebraska for the past two years, has recently accepted a position as instructor in mathematics in the University of Kansas. Some years ago Mr. Leefschetz had both hands amputated on account of electrical burns received in an accident in transformer testing. Before coming to this country he graduated from the University of Paris. After leaving Pittsburgh he took advanced mathematics in Clark University, where he received his Doctor's degree in mathematics with the highest honors ever accorded by that institution. On July 3 he is to be married to Miss Alice Hayes, who was a student in mathematics with him at Clark University. After a trip to Paris, they are to return to Lawrence, Kansas, where he will take up his work as teacher of mathematics.

Mr. E. W. P. Smith, of Cleveland, Ohio, has been working the past spring under the direction of Mr. E. P. Roberts preparing a "preliminary report on the electrification of steam railroads in Cleveland." This report was presented to Mayor Baker last month.

Mr. H. L. Garbutt, formerly of the Chicago district office of the Westinghouse Electric & Mfg. Company, has recently entered the employ of the company in the detail and supply department at East Pittsburgh, Pa.

Mr. W. B. Miser, of the Chicago district office of the Westinghouse Electric & Mfg. Company, has recently accepted the position of manager of the Jacksonville (Ill.) Railway and Light Company.

Mr. T. D. O'Conor, of the research engineering department, and Mr. H. A. Faber, of the detail and supply sales department of the Westinghouse Electric & Mfg. Company, have organized the Formica Products Company, with hedaquarters at 200 Main street, Cincinnati, Ohio, to manufacture commutator insulation, for V-rings, bushings, etc.

Mr. S. N. Clarkson, formerly of the engineering apprenticeship course of the Westinghouse Electric & Mfg. Company at East Pittsburgh, has recently been appointed assistant sales manager of the Union Electric Light & Power Company, of St. Louis, Mo.

Mr. R. W. Eaton, formerly connected with the New Haven office of the Westinghouse Electric & Manufacturing Company, has recently been appointed electrical engineer for the Connecticut Company, with offices at New Haven.

The *Southern Engineer* for June reprints the article by Mr. W. A. Dick entitled "Notes on a Large Unipolar Generator," from the JOURNAL for September, 1912.

Among the awards made during the past week for furnishing supplies for the Navy Yards, the Hemming Manufacturing Company of Garfield, N. J., have received contract for supplying a number of dies and heat-resisting molded insulation, and are very much gratified by this endorsement of their products by the naval authorities.

"RATE RESEARCH"

The Possibilities and Aims of the Work of the Rate Research Committee

The Rate Research Committee of the National Electric Light Association started out in 1911 to establish a uniform basis for electric rates which could be made standard and used throughout the country. In its work, the Committee met some almost insurmountable difficulties, in that two general systems of rate making were in vogue, one basing its differentiation entirely upon the quantity used irrespective of the length of use of maximum demand, and the other using the load factor as a basis for differentiation in price. These differences at first appeared to be basic, but a more careful study evolved the fact that the underlying principles of both systems were the same and that in one case a general average was made for all customers of a class, and in the second, the individual customer was allowed to find his own level by the application of the demand theory. The difficulty was much more manifest in the retail rates than in wholesale rates, as most companies have adopted the demand principle for the larger customers. The Committee, under the circumstances, decided that more good could be accomplished by uniformity in the mechanical details of rate and schedule making, than in any abstract study of the actual theory of rate construction and, with this in mind, it has devoted its attention for the last two years almost altogether to the matter of uniform schedules for electric light companies.

The Committee found in 1912 that one of the State Associations in cooperation with its State Commission had done considerable work along this line and it therefore joined with this Association and established a form for uniform schedules. This form with slight changes has been accepted by one of the State Commissions, and has been privately adopted by many of the companies, and it probably represents the path along which standardization in this direction will develop in the future.

The mere standardization of the existing rates of an electric company, in almost every case increases the efficiency of the rates themselves at least 100 percent. Practically every company that has attempted to standardize its rates, has seen immediately the necessity for a general house cleaning, and the rates, as a rule, are greatly simplified, and terms and conditions and riders are made uniform, and special rate clauses are in some cases eliminated, and in others greatly improved.

One of the great difficulties in the rate situation throughout the country is the fact that heretofore rates have been considered an extremely intimate and personal matter with the executives of the companies, and none of the subordinate officers or heads of departments has felt justified in taking upon themselves a careful study of rates, a subject which was so clearly considered a matter of policy, to be dealt with entirely by the chief executives of the company. As early as 1911, the Rate Research Committee recognized this difficulty and has encouraged the companies to appoint one of their junior officers or heads of departments to make a special study of electric rates, both as to the theory and the mechanism of rate making, and also to follow what is being done by the courts and commissions in the matter.

Such an officer, without assuming any executive authority can post himself so thoroughly, that when rate questions arise, for in general they come up very suddenly, the executives of the company will have at their immediate disposal, one officer who is thoroughly familiar with the situation as it exists in other companies, and with the decisions which must be considered in all rate determinations. In order to post these "Member Company Assistants" as they were called, the Rate Research Committee, in June, 1912, started a mimeographed bulletin giving abstracts of current rate decisions, each week from the data which it was receiving in its office. By June, 1912, the demands for this publication had exceeded the method of reproduction, and the Executive Committee of the National Electric Light Association authorized the Rate Research Committe to print these abstracts as a regular publication of the Association. Under the title of RATE RESEARCH, the Rate Research Committee began this printed publication, as a weekly, with the issue of October 2, 1912, and the publication met with practically instant favor from the electric light companies. In considering this publication it should be remembered that it is primarily intended as a guide to some particular officer in each electric light company, in order that he may acquaint himself with the current rate information as it may apply to the problems which confront his own company. The paper is divided into two parts, the first part containing in abstract current court and commission decisions. These are given as far as possible by direct quotation, and as the publication is on file with all of the commissions regulating electric companies, direct quotation from RATE RESEARCH can be made before Commissions. The second part is devoted to current references to all of the important electrical and technical publications. These references give, by a short abstract, the scope and general character of papers on rates and rate regulation as they appear in the current periodicals. Inasmuch as RATE RESEARCH is a weekly, these references are made promptly, and as a rule, reach the companies while the publication is still available, so that a troublesome search for the reference is unnecessary.

While a number of the attorneys of the electric companies subscribe to RATE RESEARCH, it is not primarily intended as a legal paper. It is arranged to appeal to the busy central station executive and to give him an indication, by the shortest route, of what would interest his company. If the reference is important from his viewpoint requests can be made for a complete copy of the decisions or paper before the original supply is exhausted.

The Rate Research Committee believes that if the RATE RESEARCH magazine is considered and used in the above manner, ultimately a corps of efficient rate experts will be developed throughout the country, and that the standardization of rates, and the uniformity of rate schedules will soon become an accomplished fact.

NEW BOOKS

"Magnetism and Electricity"—E. E. Brooks and A. W. Poyser. 633 pages, 413 illustrations. Published by Longmans, Green and Company, New York and London.

This is an advanced text book for students in physics or electrical engineers. It is intended to replace Poyser's "Advanced Magnetism and Electricity," originally published in 1892. Problems are freely interspersed through the text, with answers at the conclusion of the book. This work has an excellent feature of confining discussions of various features to single paragraphs headed by prominent captions. A certain part of the book is set in small type so that it may be omited by those students who do not desire to go deeply into the subject. Chapters are included on telegraphy and telephony; dynamos and motors; electric lamps, etc.

CARD FILE INDEX

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ILLUMINATING ENGINEERING SOCIETY CONVENTION

The next annual convention of the Illuminating Engineering Society is to be held in Pittsburgh during the week beginning September 22. It is expected there will be a large attendance of engineers interested in various forms of lighting. An interesting program is being prepared, and also an attractive schedule of inspection trips and entertainments.

The convention committee consists of Mr. C. A. Littlefield, New York Edison Company, chairman; Mr. P. S. Millar, Electrical Testing Laboratories, president of the society; Mr. H. S. Evans, Macbeth-Evans Glass Company, Pittsburgh; Mr. W. A. Donkin, contract manager of the Duquesne Light Company, Pittsburgh; Mr. D. MacFarlan Moore, General Electric Company, Harrison, N. J.; Mr. M. C. Rypinski, Westinghouse Electric & Mfg. Company, New York City; Mr. C. J. Mundo, General Electric Company, Pittsburgh; Mr. J. C. McQuiston, Westinghouse Electric & Mfg. Company, Pittsburgh; Mr. W. J. Serrill, United Gas Improvement Company, Philadelphia; Mr. S. B. Stewart, Philadelphia Company, Pittsburgh; Mr. T. J. Pace, Westinghouse Electric & Mfg. Company, Pittsburgh; and Prof. H. S. Hower, Carnegie Technical Schools, chairman of the local section of the society. Mr. W. A. Donkin was selected chairman of the local committee on arrangements which will have charge of the convention. Mr. J. C. McQuiston was appointed chairman of the publicity committee and will make all arrangements for advertising the convention.

BAKELITE PATENT RECOGNITION

As a result of negotiations between the General Bakelite Company and the Condensite Company of America, the suits brought by the former against the latter and its customers for alleged infringement of the Bakelite patents, have been withdrawn, and the Condensite Company, recognizing the pioneer character of Dr. L. H. Baekeland's work, has acknowledged the validity of the Bakelite patents in suit and some others, and will pay substantial royalties thereunder. The General Bakelite Company will continue the manufacture of Bakelite under its numerous patents, and the Condensite Company will manufacture Condensite under the Aylsworth patents, as well as the license just granted for such of the Baekeland patents as are broad enough to cover Condensite. This recognition of the force and validity of the principal Baekeland patents by the only other manufacturer of condensation products is a confirmation of the Bakelite Company's claims for the broad scope and pioneer character of these patents. There is much that is old in the art of making phenolic condensation products, but Dr. Baekeland was the first to make practical application of what theretofore had been chiefly laboratory experiments.

CATECHISM ON ALTERNATING-CURRENT APPARATUS

As a companion book to "Catechism on Direct-Current Apparatus," Fairbanks, Morse & Co., of Chicago, have recently issued a Catechism on Alternating-Current Apparatus. It is a booklet dealing with the construction and application of generators, motors and auxiliary equipment in which is given in condensed question and answer form a very great amount of practical information. From a short description of how alternating-current is produced arguments are given not only on general points of construction and operating characteristics of equipment but also on such points as: Advantages of alternating-current, advantages of direct-current, electrical characteristics that must be considered in comparing alternators, advantages and limitations of synchronous motors, split-phase motors, etc., etc. Copies will be sent to interested parties on request to the Chicago office of the company.

MASTIC FLOORING FOR INDUSTRIAL PLANTS

The problem of flooring the factory is a difficult one, but the obstacles which present themselves in the average plant seem at last to have been overcome by a flooring material known as J-M Mastic. This flooring is unequalled for factory and warehouse use, even under the heaviest trucking conditions, and on account of its noiseless character is a boon in plants where there is considerable trucking. Another feature in its favor is its peculiar holding quality which prevents slipping. J-M Mastic Flooring provides a surface that is waterproof and at the same time practically wear-proof under ordinary service conditions. It is also unaffected by acids, alkali and brine. Being waterproof it is absolutely sanitary, as it can be quickly and thoroughly cleaned by the simple process of flushing, after which it dries out immediately.

THE
ELECTRIC JOURNAL

Vol. X AUGUST, 1913 No. 8

The Increase in Transmission Voltages

That transmission voltages are still on the increase is made evident in this issue of the JOURNAL, in which there are five articles dealing directly or indirectly with electrical apparatus suitable for transmission voltages of 150 000 volts and above. Specific apparatus for a western transmission system of 150 000 volts nominal voltage is particularly described. In this case the apparatus has been designed to withstand a test voltage of two and one-half times normal or 375 000 volts to ground. According to the standards commonly used and accepted by most engineers as sufficient (the A. I. E. E. standard of double normal voltage) this apparatus is suitable for operation on a transmission voltage of 187 000 volts, as far as insulation is concerned. This voltage is nearly 35 percent higher than any transmission voltage used anywhere and is 70 percent higher than the next lower transmission voltage (110 000 volts) that has come into general use. From this it can be seen not only that transmission voltages are on the increase, but that the rate of increase is certainly not slow.

The physical size of such high voltage apparatus is one of the noticeable features. This is shown by a number of the illustrations of transformers and other apparatus in this issue. It is brought out in a startling manner by Mr. Dann's statement that a 40 000 k.v.a. transformer designed for use on 22 000 volts would be no larger in physical dimensions than the 4 500 k.v.a. 150 000 volt transformer which he describes.

Probably the best index of the advance of the art of designing high tension transformers are the results that have been achieved on terminal bushings. The article by Messrs. Fortescue and Mateer, describing the condenser type of terminal and giving a large amount of data, will be of unusual interest to the engineering profession.

If the statement had been made five years ago that a 150 000 volt bushing could be made so as to pass through an opening in a metal transformer tank not more than 10 inches in diameter and suitable for a test of not less than 375 000 volts to ground, it would hardly have been credited. Still more surprising is the fact that this is accomplished without stressing the dielectric properties of the material used beyond a very conservative value. Further, the almost entire absence of corona at any point, even at maximum test voltage indicates that even the air surrounding these terminals is nowhere stressed to its breaking point. Such a result has been obtained only by a thorough understanding of the principles governing the distribution of potential and particularly by the use of condenser principles, whereby a proper potential distribution may be obtained.

The results of the test and the operation of these terminal bushings make it necessary for most engineers to revise their ideas concerning the dielectric strength of air. Many engineers have derived their ideas on this subject from the sparking distances across a needle point air-gap. Ten thousand volts per inch is the rough figure that many high tension engineers carry in their minds as the figure for the dielectric strength of air, and this figure comes directly from the curve which connects potential and sparking distance for needle points. As a matter of fact, air uniformally stressed will stand five or six times this amount, all due to the fact that the needle gap gives such bad voltage gradient. By designing the terminals and shaping the static fields properly a very considerable proportion of this ideal ultimate may be realized in actual practice. However, it is only by the application of proper principles, such as is so beautifully illustrated in the condenser terminal, that any such result can be approached.

It seems probable that the next ten years will not bring about any such increase in transmission voltages as has been witnessed in the last ten years. The question of economics alone, bearing in mind the rapidity with which apparatus increases in cost with voltage, would indicate this result. However, he is a rash man, in view of what has taken place during the last decade, who would make any definite prediction along this line.

P. M. Lincoln

A New Kind of Engineering

The value of much of the product of modern industrial concerns depends on the exactness with which the various manufacturing processes can be carried out. In small establishments, where processes are relatively few or simple, the details, when once established, may be transmitted from superintendent to foreman, and foreman to workman, with comparatively little change, if care is exercised. In larger establishments, where processes are many and complicated, where foremen and workmen change, and where new processes are continually required, something more than tradition and word of mouth is needed to keep important processes from being changed, either through oversight or intention. Many manufacturing processes are arrived at only after careful scientific work and, where limits of temperature are close or where variations in processes must be made for commercial variations in material or where chemical reactions must take place in a given order, it becomes absolutely necessary to give foremen and workmen definite instructions as to the way in which their part of the work should be done.

When new products are to be manufactured, requiring new processes, the experimental part of the work should be completed before regular manufacturing is begun; and the steps in the processes, together with the limitations in each step, should be known, and the information presented in such form that each workman can be instructed as to what should be done and what should not be done in order to secure the desired results.

In some lines of work there is a feeling on the part of the workman that his personal knowledge and skill is his "stock in trade" which permits him to hold his position, and that to give this information to others in such form that additional workmen or his successors may be trained, will result in his losing his position or having his income reduced. This feeling on the part of many workmen, and even on the part of those in charge of certain classes of work, is at the bottom of not the least of the difficulties in the way of getting the data in connection with various processes in large manufacturing concerns into such shape that they may be transmitted to others.

The tremendous increase in the amount of work done by various industrial establishments, requiring either a special skill on the part of the workmen or a set of directions which can easily be followed, has made it necessary to provide some sort of consistent plan by means of which the manufacturing company can insure that its products will be kept at a uniformly high grade of excellence. With the multitude of new materials, and new requirements which are constantly arising, the only safe plan is to describe each process in the form of a specification, so that when once in satisfactory operation it may be continued regardless of change of foreman, or workman, or material.

All this has led to a new kind of engineering, which we may call "Process Engineering" and the development of the "process" specification. It is a significant fact that in a large industrial establishment, there are few processes, no matter how simple, which cannot be bettered or cheapened by careful scientific work and the standardization of the ways and means by which they are carried out. It has further been observed that, in general, instead of taking away the job of the workman, who is more or less skilled in his particular branch, this standardization of processes adds to his efficiency and his ability to better both his own condition and that of his employer.

A satisfactory process specification, moreover, allows the use of entirely commercial materials with their necessary commercial variations, and provides for the transformation of these materials into the desired manufactured products with limits in variation not greater than may be commercial for these particular products. Where exceptional quality is required, it also provides a means of procuring this exceptional quality by taking into account all the variations in materials and methods, and selecting those which will give the best result. When process specifications are properly prepared and properly carried out, heat treatments of steel, the manufacture of alloys, the manufacture of insulating materials and the processing of high voltage transformers, all become matters of exact science rather than hit-and-miss methods depending on the individual skill of the workman.

It is probably not too much to predict that this definite method of taking care of processes, originating, as far as the writer knows, about ten years ago in the works of the Westinghouse Electric & Mfg. Company, and outlined by the Messrs. Lynch, in the article entitled, "The Value of Process Specifications" in this issue of the JOURNAL, will be found of great value in many industrial establishments.

C. E. SKINNER

Tendency Toward Refinement in Electrical Equipment

One tendency of modern electrical apparatus is toward refinement and special adaptation to requirements. Such refinement, while making the apparatus more efficient and more satisfactory for the purpose desired, often involves more skilled care and attention. One common example of this is the mercury rectifier-metallic flame arc light. A light of desirable whiteness and in suitable units is obtained at an attractively low cost for energy. These desirable features are obtained, however, by a refinement of the electrical equipment that makes it rather more senstive to the care received than some of the older and less efficient and less satisfactory systems of illumination.

The multiple-unit control of electrically propelled cars and locomotives by means of unit switches is another illustration of this tendency, that has become well established. Unquestionably a higher degree of skill is required to care for a modern car with its collection of contactors, relays, limit switches, etc., than to file up or replace contacts on a drum controller. The advantages, however, have proved to be well worth the complication. In fact it has often been the confronting of a severe necessity rather than a consideration of advantages that has prompted the use of such refinements.

The article in this issue by Mr. G. C. Dill on "Electrolytic Lightning Arresters" shows the effect on this type of apparatus of the demand for greater effectiveness and adaptability to special requirements. Some of the older types of arresters could be connected up and forgotten and, in fact, often were, until they went up in a display of fireworks. As Mr. Dill has shown, the type of arrester, which has now come into common use throughout the country, requires particular care and attention. Like the other specialized apparatus, however, it repays this care with an effectiveness which apparently can be obtained in no other way.

R. P. Jackson

THE CONDENSER TYPE OUTLET TERMINAL

THEORY OF DESIGN.

C. FORTESCUE

UNTIL the development of the condenser type terminal, the outlet terminal was one of the chief limitations in the design of high voltage transformers and circuit breakers. As early as 1906, two years before the condenser type terminal was introduced, experiments were made with various types of terminals for voltages greater than 66 000 volts; among these was the oil filled type. This type of terminal gave so much trouble on account of its tendency to leak oil that it was finally abandoned by the company with which the writer is connected without being placed in commercial service. In another form of terminal which was developed at the same time, use was made of a large Portland cement bushing within which was cemented a micarta covered brass tube. This type of terminal is doing excellent service at the present time; in fact, the first 100 000 volt transformers manufactured for power purposes (and which were actually put into service at 117 000 volts) were equipped with this terminal, and have been in uninterrupted service since 1907.

The use of condensers to distribute the stress internally and externally was a distinct forward step in the theory of terminal design, and the commercialization of the condenser type terminal and the suspension type insulator marked the beginning of a new era in high voltage transmission. At present a condenser type terminal may be designed and constructed for any voltage. The cost is the sole limitation and this varies approximately as the cube of the voltage.

In order to obtain a mental conception of the principle upon which the condenser type terminal depends, imagine a large circular disc, Fig. 1, a distance *d* from an infinite plane at zero potential. The electric field between the disc and the plane may be imagined as laid out in equipotential surfaces, decreasing in potential from the disc to the plane by equal infinitesimal decrements. If the diameter of the disc is large in proportion to its distance from the plane these surfaces will coincide in the space between the disc and the plane with a system of equi-spaced planes parallel to the disc and the zero potential plane. Assume that on each of these surfaces a ring of any diameter and of infinitesimal area of cross-section is placed, and let it be kept at the same potential as the surface on which it lies. These rings will not disturb the electric field and, since they are infinite in number, their envelope* will enclose a space between the disc and the zero potential surface. Within this space any system of electric field distribution may be substituted for that due to the disc and plane, so long as it results in the same values of potential at each point of this surface as those due to the disc and plane, without changing the electric intensity in the external field. A system of concentric cylindrical conductors may, therefore, be placed in this space, the ends of which coincide with the rings and their respective capacities being such that each will have the same potential as that of the ring with which its end coincides. These cylinders may be considered as extending through the zero potential plane, and ending in a similar system of rings lying on the equipotential surfaces of another disc and another zero potential plane parallel to the first. With a proper relation of diameters of rings to lengths of cylinders, the ends of each cylinder will lie on the equipotential surface of both the fields between the discs and planes which have the same potential as the cylinder.

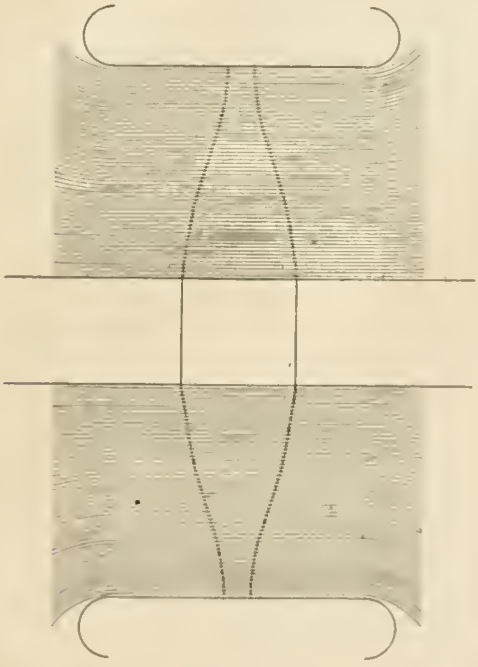

FIG. 1

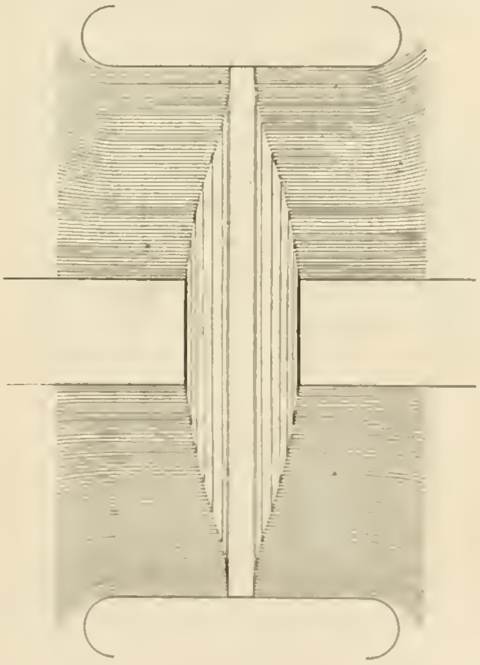

FIG. 2

The space enclosed by the envelopes of the ends of the cylinders and the external conducting cylinder between the two parallel zero potential planes, may be regarded as an outlet terminal. The zero potential surfaces may be the cover of a transformer, a roof or any structure through which the outlet may pass. Such a terminal with an infinite number of layers would have a surface strength depending only upon the rupturing voltage of the air between the discs and zero potential planes.

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*If all the members of the family of curves $\Phi(xyzc) = 0$ be drawn, which correspond to a system of infinitesimally close values of the parameter c, arranged in order of magnitude, consecutive curves being any two curves which correspond to two consecutive values of c; then the locus of the ultimate point of intersection of consecutive members of the family of curves, is called the envelope of the family.

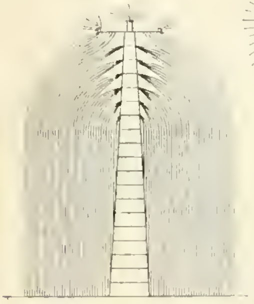

FIG. 3

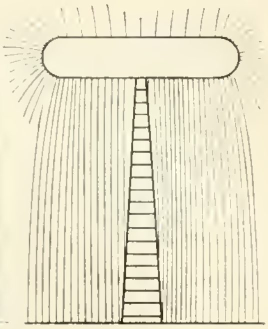

FIG. 4

In actual practice the steps between rings must be finite. There will, therefore, be a little concentration of dielectric flux at the ends of each cylinder. One way to reduce this concentration is to make the diameter of the terminal larger; another is to seal in the surface with a dielectric compound which is stronger than air, has a higher specific inductive capacity and will, therefore, reduce the stresses at the ends of the cylinders and at the same time be able to withstand them better than air. The external surface of this dielectric must coincide with the direction of the flow lines or Faraday tubes from the discs to the planes. The approximately correct shape will, therefore, be an external cylinder concentric with the terminal.

The dielectric between the cylinders may be of any homogeneous material of high breakdown strength and low dielectric loss. If the lengths of the cylinders, and the differences of the logarithms of consecutive radii decrease in arithmetic progression, and if the decrements of the two series bear the proper relation to each other, the result will be a condenser terminal, having equal capacities between adjacent cylinders. The relations between the diameters and lengths of the conducting tubes are obtained by simple mathematical processes* and with proper materials the terminal may be accurately constructed.

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*Let r be the radius of the inner cylinder,
r_m, the radius the outer cylinder,
l_o, the length of the inner cylinder,
l_m, the length of the outer cylinder,
l_1, l_2, l_{m-1}, the lengths of the various steps,
F_o, the radial intensity at the surface of the inner cylinder, expressed in kilovolts per unit length,
F_m, the radial intensity at the surface of the outer cylinder, expressed in the same terms.

In a paper presented before the American Institute of Electrical Engineers in March, 1913, it is shown that the prevalent idea of surface creepage is incorrect and that the strength over any surface of insulating material depends merely upon the intensity to which the air along the surface is stressed. Porcelain is a material of high specific inductive capacity and, therefore, where it is present in large masses in forms whose outlines do not conform to the natural flow lines, these flow lines or Faraday tubes concentrate at its surfaces, producing corona even at moderate voltages. In most insulators and outlet terminals using porcelain, some corona is present at working voltages and at test voltages manifests itself by the phenomenon of creepage over the surface of the porcelain. In the condenser type terminal there is no concentration of dielectric flux at the surface of the terminal if the number of steps is infinite, and in commercial designs, where the steps are finite in number, the little concentration that exists due to this fact is rendered inocuous by the dielectric filler now provided on the air end of all terminals inside the cylindrical casing. On the oil end the oil prevents the formation of corona until a voltage is reached much in excess of the maximum test voltage for which they are designed.

Let F_n, the radial intensity at the surface of the nth cylinder.

V_m, the potential of the inner cylinder, that of the outer being zero.

$S = l_0 - l_1$ and $mS = l_0 - l_m$, the first being the difference in length between consecutive steps and the second being the total difference.

Since the total dielectric strength is constant

$$F_0\,l_0\,r_0 = F_n\,l_n\,r_n = F_m\,l_m\,r_m \qquad \text{(1)}$$

and therefore

$$\frac{r_m}{r_0} = \frac{F_0\,l_0}{F_m\,l_m} \qquad \text{(2)}$$

The intensity F at any cylinder in the terminal of radius r having a length l parallel to the axis will be by the relation, (1)

$$-\frac{dv}{dr} = F = \frac{F_0\,l_0\,r_0}{rl} = \frac{F_m\,l_m\,r_m}{rl} \qquad \text{(3)}$$

Since the potential of each cylinder is proportional to its length over l_m

$$V = \frac{V_m(l - l_m)}{l_0 - l_m}$$

and therefore

$$dv = \frac{V_m}{l_0 - l_m}\,dl \qquad \text{(4)}$$

Substituting this in (3) and arranging terms

$$\frac{F_0\,l_0\,r_0}{r}\,dr = -\frac{V_m}{l_0 - l_m}\,ldl$$

$$\text{or } F_0\,l_0\,r_0 \log_e v = A - \frac{V_m\,l_0}{2(l_0 - l_m)} \qquad \text{(5)}$$

In some cases, in considering the principle of the condenser type terminal, more emphasis has been placed on uniform radial stress than on the more important feature of uniform surface stress. The efficiency in design of a terminal must be considered not only from the point of view of the effectiveness of application of the insulating material around the lead but also of the uniformity of stress in the region external to the terminal. Thus, instead of being designed with a disc at its tip the terminal might have been designed with a sphere, and instead of having a plane at ground potential a larger sphere might have been used. The design under such conditions would have depended on the field between two spheres, the larger of which is at zero potential. The terminal having uniform distribution of stress in the material, which has been described as theoretically ideal, is seen to be very defective, when considered from the broader point of view, since

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We thus have for the inner and outer cylinders the relation

$$F_o l_o r_o \log_e r_o = A - \frac{V_m l_o^2}{2 (l_o - l_m)} \qquad \text{(6)}$$

$$F_o l_o r_o \log_e r_m = A - \frac{V_m l_m^2}{2 (l_o - l_m)} \qquad \text{(7)}$$

Subtracting (6) from (7) we have

$$F_o l_o r_o = F_m l_m r_m = \frac{V_m (l_o + l_m)}{2 \log_e \frac{r_m}{r_o}} = \frac{V_m (l_o + l_m)}{2 \log_e \frac{F_o l_o}{F_m l_m}} \qquad \text{(8)}$$

Whence we have

$$r_o = \frac{V_m (l_o + l_m)}{2 F_o l_o \log_e \frac{F_o l_o}{F_m l_m}} \qquad \text{(9)}$$

$$r_m = \frac{V_m (l_o + l_m)}{2 F_m l_m \log_e \frac{F_o l_o}{F_m l_m}} \qquad \text{(10)}$$

Eliminating *A* from (5) by means of (6) and substituting for $F_o l_o r_o$ from (8) we have

$$\log_e r = \log_e r_o + \frac{l_o^2 - l^2}{l_o^2 - l_m^2} \log \frac{F_o l_o}{F_m l_m} \qquad \text{(12)}$$

These may be put into exponential form, thus:

$$r = r_o \left(\frac{F_o l_o}{F_m l_m}\right)^{\left(\frac{l_o^2 - l^2}{l_o^2 - l_m^2}\right)} = r_m \left(\frac{F_m l_m}{F_o l_o}\right)^{\left(\frac{l^2 - l_m^2}{l_o^2 - l_m^2}\right)} \qquad \text{(13)}$$

In the above discussion the steps have been assumed infinite in number. Considering the steps to be *m* in number—

$$\log_e r_n = \log_e r_m - \frac{2 (m - n) l_m + (m - n)^2 S}{m (l_o + l_m)} \log \frac{F_o l_o}{F_m l_m} \qquad \text{(14)}$$

the resulting potential at the surface of the terminal does not correspond to the natural distribution over the same surface in space. The result must, therefore, be concentration of stress at the edges of the tin foil in such a terminal.

Another point in the theory of the condenser type terminal that many find difficult to understand is that the sharp edges of the tin foil cylinders have no bad effect while a similar projection on the disc at the top of the terminal will show corona. The explanation of this is as follows:—The edge of each tinfoil cylinder has a certain definite potential which is determined by its capacity with respect to the remaining cylinders; it has also a tendency to assume a certain potential by virtue of its capacity to ground through the external field. If these two potentials agree in value, the edges of the cylinders will lie on equipotential surfaces of the same value set up by the external system which in-

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Taking the expression for three consecutive radii numbered ($n - 1$), n and ($n + 1$), and subtracting the second from the third, and the first from the second—

$$\log_e \frac{r_n}{r_{n-1}} = \frac{2\,l_m + \{2\,(m - n) + 1\}\,S}{m\,(l_o + l_m)} \log_e \frac{F_o\,l_o}{F_m\,l_m}$$

$$\log_e \frac{r_{n+1}}{r_n} = \frac{2\,l_m + \{2\,(m - n) - 1\}\,S}{m\,(l_o + l_m)} \log_e \frac{F_o\,l_o}{F_m\,l_m}$$

$$\log_e \frac{r_n}{r_{n-1}} - \log_e \frac{r_{n+1}}{r_n} = \frac{2\,(l_o - l_m)}{m^2(l_o + l_m)} \log_e \frac{F_o\,l_o}{F_m\,l_m} \quad \text{......} (15)$$

Thus it is seen that the logarithms of the ratios $\frac{r_n}{r_{n-1}}$ form an arithmetic progression. A complete set of formulæ for designing a condenser type terminal is given below:

$$r_o = \frac{V_m(l_o + l_m)}{2\,F_o\,l_o \log_e \frac{F_o\,l_o}{F_m\,l_m}} = \frac{0.4343\,V_m\,(l_o + l_m)}{2\,F_o\,l_o \log_{10} \frac{F_o\,l_o}{F_m\,l_m}} \quad \text{............} (16)$$

$$r_m = \frac{V_m(l_o + l_m)}{2F_m\,l_m \log_e \frac{F_o\,l_o}{F_m\,l_m}} = \frac{0.4343V_m\,(l_o + l_m)}{2F_m\,l_m \log_{10} \frac{F_o\,l_o}{F_m\,l_m}} \quad . (17)$$

$$\log \frac{r_m}{r_{m-1}} = \frac{2l_m + S}{m\,(l_o + l_m)} \log \frac{F_o\,l_o}{F_m\,l_m} \quad \text{..........................} (18)$$

$$\log \frac{r_{m-1}}{r_{m-2}} = \log \frac{r_m}{r_{m-1}} + \frac{2(l_o - l_m)}{m^2(l_o + l_m)} \log \frac{F_o\,l_o}{F_m\,l_m} \quad \text{......} (19)$$

$$\log \frac{r_{m-2}}{r_{m-3}} = \log \frac{r_{m-1}}{r_{m-2}} + \frac{2(l_o - l_m)}{m^2(l_o + l_m)} \log \frac{F_o\,l_o}{F_m\,l_m} \quad \text{......} (20)$$

$$\log r_n = r_m - \frac{2\,(m-n)\,l_m + (m - n)^2 S}{m(l_o + l_m)} \log \frac{F_o\,l_o}{F_m\,l_m}$$

$$= \log r_o + \frac{2\,n\,l_o - n^2\,S}{m\,(l_o + l_m)} \log \frac{F_o\,l_o}{F_m\,l_m} \quad \text{..............................} (21)$$

Equations 18 to 21 are true for either common or Naperian logarithms.

cludes the tip of the terminal and the ground potential plane, and the sharp edges will have no disturbing effect. If they differ in potential there will be a concentration of electric flux at the edge of the cylinder which will cause the external field form to change from its natural value so as to agree with the distribution over the surface of the terminal and in this case some disturbance may be produced. When conductors with sharp edges are raised to a potential above ground in the absence of external field due to some other source, the stresses are those set up by its own field and are higher at the edges, the sharper the edges. The same conductor at the same potential could be introduced in a field of force in such a manner that it would cause no increase in the stress, provided that it were an infinitely thin shell.* If its thickness were finite the stress would be increased, and in this case the thicker the conductor the greater the stress will be.

There seems to be a common idea among many engineers, and unfortunately it is not limited to those who have had no experience in insulation work, that the flash over voltage of a terminal is determined by the spill over voltage between needle points set at a separation equal to the height of the terminal above the ground plane. This idea is not in accord with the facts. The rupture strength of the air along the surface of a dielectric depends on the intensity of the stress to which air is subjected. The intensity of the stress may be enhanced by the presence of the dielectric but generally the forms of surface and electrodes may be so chosen that the presence of the dielectric does not affect the strength of the air path over the surface. Terminals have been constructed in which the average stress to which the air path over the surface of the dielectric was subjected before rupture took place was as high as 30 000 volts per inch, three times the average break down strength of the same distance in air between needle points.† An insulator was also constructed on the same principle which withstood an average stress at breakdown of 25 000 volts per inch and would hold up indefinitely at an average stress of 21 000 volts per inch, which is twice the average breakdown strength per inch between needle points set at a distance equal to the sparking distance along the surface.

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*See "A Study of Insulation Problems," in the JOURNAL for July, 1913, page 651, or "The Application of a Theorem of Electrostatics to Insulation Problems" in the A. I. E. E. proceedings, March, 1913.

†See "Air as an Insulator When in the Presence of Insulating Bodies of Higher Specific Inductive Capacity," in the A. I. E. E. proceedings for March, 1913.

Three years ago a test was made in air on the oil end (which is 12½ inches long) of a 100 000 volt condenser terminal. The terminal was set up with the end of the outer cylinder flush with a platform of wood covered with tinfoil. The central cylinder at the short end was surmounted by a sphere 10 inches in diameter (which was not the correct form of electrode for this particular terminal). Under these theoretically imperfect conditions, this terminal was run at 125 000 volts for 80 hours and at the end of this time was tested up to 175 000 volts before breaking over the surface. This condenser terminal, which had 25 layers of insulating material, operated continuously at the rupturing voltage between needle points set at a distance apart equal to its creepage surface, and was able to withstand without injury a rupturing voltage 40 percent higher. With more favorable conditions of test and more layers of insulation, very much higher test voltages for a given length may be obtained with the condenser type principles.

The conclusion to be drawn from the foregoing discussion is that the commercially efficient design of condenser terminal must be a compromise. If a very short terminal is desired more layers must be used and the working intensity in the material must also be reduced, thus adding to the cost of manufacture. The ideal terminal commercially will be moderate in length and will have a moderate number of layers and, therefore, it will not require such precision and care in manufacture as the extremely short terminal.

CONSTRUCTION AND APPLICATION

J. E. MATEER

The commercial condenser terminal of today consists of the condenser proper on which is mounted a flange of metal. On the air end this combination carries a cylindrical casing of bakelite micarta.* The space between the casing and the tapered portion of the condenser is filled with a molten insulating compound which is solid at all operating temperatures, but is not brittle. At the end of the casing a static shield is secured, of a form that prevents any corona from the connectors from reaching the micarta casing. On out-door apparatus, the micarta casing is replaced by a series of porcelain rain shields. The lower end of the condenser is provided with a metallic sphere in the case of transformers or a suitable contact in the case of a circuit breaker. The circuit breaker contact for high voltages (88 000 volts and upwards) is carefully shaped to prevent the formation of corona under oil. The spheres for transformer terminals also are proportioned to give the same freedom from corona under oil. These allow the placing of the terminals in oil much closer to parts of ground potential than could be done otherwise without interposing barriers of solid dielectric material. The shapes of these parts also have a distinct influence in reducing the amount of surface necessary to prevent breakdown between the end of the central conductor and the outer grounded cylinder.

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*See description of this material in the JOURNAL for July, 1913, p. 645.

The central conductor may be hollow or solid as the required conductivity may demand. For most transformer work the center is a hollow metal tube of such a diameter as will be mechanically rigid. When desirable the fittings are designed so that the lead to the windings may be drawn through this tube without the necessity of getting beneath the surface of the oil to connect with the windings. The space between the flange and the condenser is filled with an oil proof cement which does not soften by heat.

The condenser proper seems to be misunderstood in some quarters, and it is the purpose of this article to give a more accurate idea of its nature as now produced. In effect, it consists of concentric insulating cylinders (varying in length by a constant difference and varying in thickness along a logarithmic curve) with a layer of metal foil between them about 0.003 inch thick. Each layer of metal has the same length as the insulating cylinder on its outer surface and is so placed as to be completely covered by it.

Until the invention of the micarta process a satisfactory condenser terminal could not be made. Micarta is made up of a paper coated with a specially prepared shellac which is dried until all solvent and moisture are removed. The material is built up in layers by machinery which heats and sticks the layers together automatically. The cylinders are not made separately and forced over one another, but are built directly over one another. By this means the diameters do not vary from their theoretical value by more than the thickness of the material (0.005 inch) and the thickness of the walls is accurate to within five percent of the predetermined value. The entire process is continuous and results in a hard homogeneous material which is entirely free from weak spots.

After removing from the special machine, the cylindrical forms (Fig. 5 *a*) are turned in an engine lathe into their final form (Fig. 5 *b*). The last particles of metal foil are removed by hand so that there is no chance of cutting too deep at the ends of the steps. The terminal is returned to the lathe and after smoothing with sand paper the outer metal cylinder is applied. This consists of a band of wire, drawn tight and soldered along its length at numerous points. Such a band is well adapted to cementing in flanges as its surface grips the terminal and the cement firmly without injuring the terminal. The entire terminal is given about six coats of a baking varnish that is oil and water proof, but not brittle.

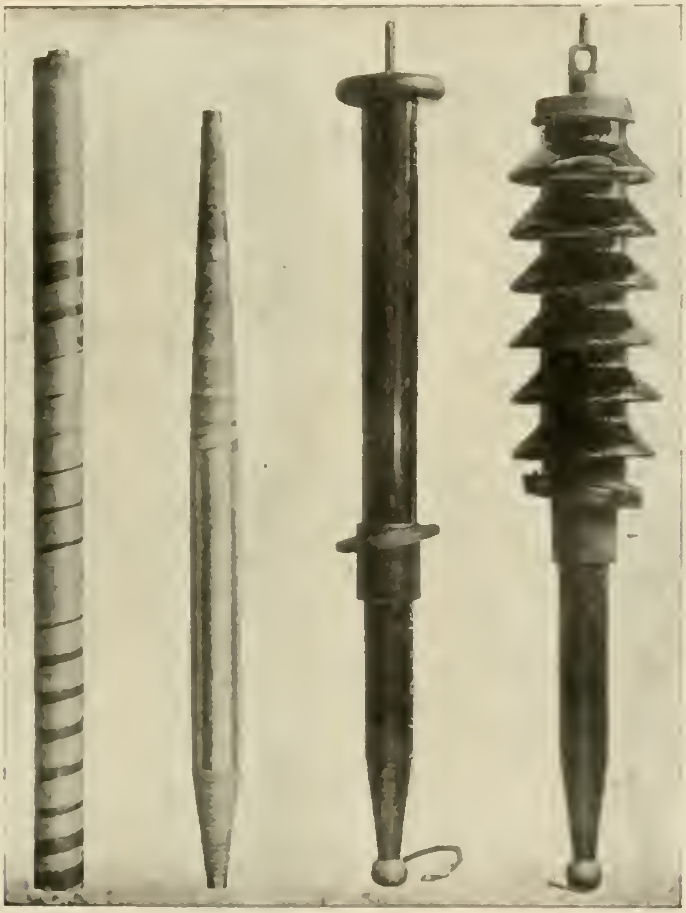

FIG. 5—(a), (b), (c) and (d)

a—Condenser as taken from machine. *b*—Same terminal turned and ready for varnishing. *c*—Assembled with flange and micarta tube for indoor transformer. *d*—Assembled with flange and porcelains for outdoor service

In order to guard against defects of material or treatment the terminals are subjected for 48 hours to a voltage 15 percent greater than that they will receive in service. This voltage is impressed at 60 cycles between the central conductor and the outer band of wire. The terminals must not show any appreciable temperature rise from internal losses during this period. They are then tested at 2.75 times service voltage for one minute before assembling in their flanges. This test is much below their puncturing voltage, but until they are mounted in flanges and fitted with casings and static shields, higher tests may produce flashing over their surfaces due to concentration of static field at the ends of the central conductor and metallic layers. Such terminals, when completed, will not heat from dielectric loss at any voltage they will receive in the service for which they are designed, and will not puncture on a one minute test at any voltage below their flashover point.

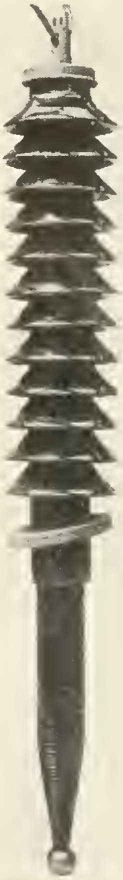

FIG. 6

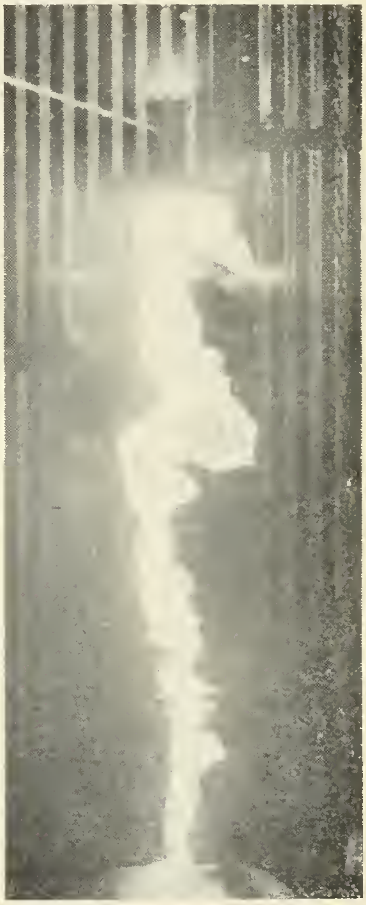

FIG. 7

FIG. 6—STANDARD 110 000 VOLT TRANSFORMER TERMINAL FOR OUTDOOR SERVICE

FIG. 7—THE SAME TERMINAL AS SHOWN IN FIG. 6 FLASHING OVER AT 270 000 VOLTS UNDER A SPRAY OF 0.4 INCH PER MINUTE

The earlier applications of condenser terminals were without static shields (they are still omitted at 66 000 volts and below except for very short terminals). They also had no cylindrical casings on the air end. The addition of these features has greatly increased their flashover voltage and increased their ability to resist bad conditions of moisture.

The static shields now used have a flat surface at right angles to the axis of the terminal and the edge rolls away from the terminal condenser. They vary in size from nine inches in diameter on terminals for service voltages of 66 000 to 115 000 volts, inclusive, to 72 inches in diameter on terminals designed for 500 000 volt transformers. The edges of the smaller shields are rolled to a one inch radius and the larger to a 7.5 inch radius. When the static shield is of sufficient diameter the cylindrical casing may be omitted, yet no corona appears at the ends of the

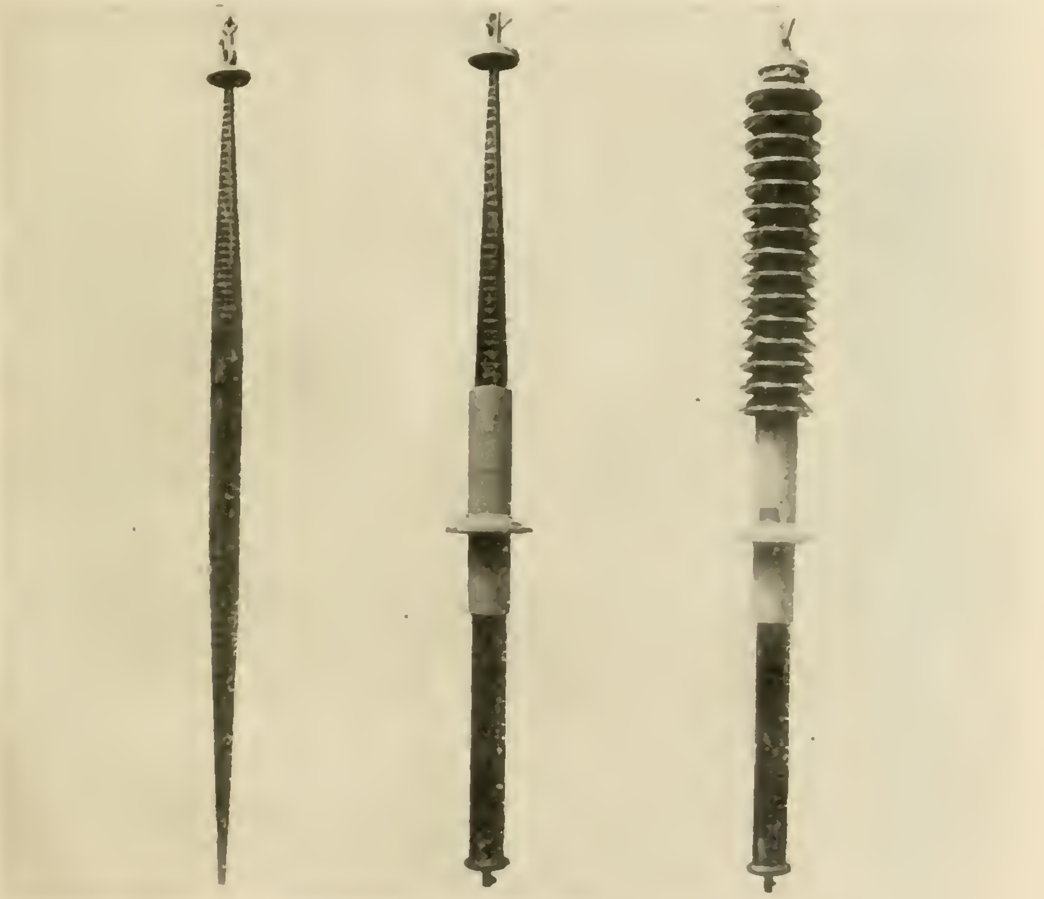

FIG. 8—(a), (b) and (c), ROOF ENTRANCE BUSHING

The diameter of the condenser is 6.64 inches. The diameter of hole required is 9.5 inches to allow its introduction into a roof with sufficient clearance to prevent injury to the terminal.

a—Condenser for roof entrance. *b*—Same terminal assembled with flange with micarta casing on indoor end. *c*—With roof entrance complete metallic layers and flashover takes place from the edge of the shield to the cover of the transformer tank.

On power transformers with two or more outlet leads the diameter of the shield is limited, although reducing the distance between the tips of the terminals by the use of static shields with large rolls on the rims tends to increase the voltage required to break down the air between them, if not carried to extremes. The proper diameter suited to the particular application must be found by experimental research. The experience of the designers at present is sufficient to enable a proper selection to be made for any purpose required.

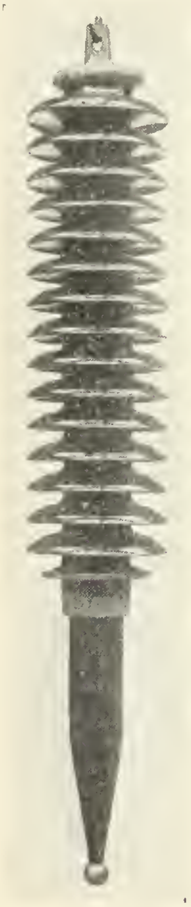

FIG. 9—OUTDOOR CONDENSER TERMINAL FOR 150 000 VOLT TRANSFORMER

In order to show the phenomenal strength of these terminals as now designed and manufactured, descriptions of several are given with considerable detail. No attempt is made to compare dimensions with other types as no other type of terminals known to the writer can approximate the results herein given.

The 66 000 volt terminal shown in Fig 5 *c*, has a dry flash-over voltage of approximately 220 000 volts. The indoor terminal has a creepage surface in air along the cylinder from the flange to the static shield of 25.5 inches. The number of insulating layers is 17. The greatest diameter of the insulation is 4.09 inches and of the central conductor 1.75 inches. The flashover of the outdoor terminal, Fig. 5 *d*, under a spray of 0.25 inches per minute directed at 45 degrees is approximately 155 000 volts. At 165 000 volts dry no corona appears on the insulating surfaces of either terminal nor is there any corona at 135 000 volts on the outdoor terminal when under the spray test, except at the top metal bell.

Tests were made on standard 88 000 volt terminals for a firm of well-known engineers as follows:—The terminal had 22 insulating layers; diameter of central conductor, two inches; outside diameter of insulation, 5.24 inches; creepage surface from wire band to static field, 37 inches. Two terminals were tested, one with a compound-filled micarta casing and the other without. The flashover voltage of the terminal with casing was in excess of 300 000 volts, which was the highest voltage obtainable at the place where tests were made. There was no corona on the insulating surfaces of the terminal at this voltage. The terminal without casing flashed over repeatedly at 285 000 volts. Both terminals held 220 000 volts without distress for five minutes, and after these severe conditions a test for 100 hours at 110 000 volts, 60 cycles without appreciable rise of temperature. The test at 220 000 volts was then repeated without injury to the terminals. Various layers of one terminal were short-circuited and the reduction of flashover voltage was proportional to the number of layers short-circuited.

Some 88 000 volt terminals in service on a circuit breaker during a severe winter and without protecting casings on their stepped surfaces were exposed to water which came through the outlet apertures in the wall and, running down the conductors, froze on their surfaces until they were coated with ice. When the ice melted they were somewhat damaged on part of the surface, but with about one-third of the creepage surface carbonized and short-circuited by static leakage these terminals continued to give service for some months until removed and replaced by others provided with casings.

A standard indoor transformer terminal for 100 000 volt service, having a creepage surface along the casing of 42 inches, was submitted to a spray of 0.2 inch per minute. At 60 000 volts there was very little corona. At 100 000 volts the terminal began to give off steam from the rapid evaporation of the water on its surface, but was otherwise uninjured, and when wiped dry stood a test of 250 000 volts for one minute without any signs of distress. This test was repeated on several terminals with like results, and constituted part of the contract test in an installation involving about 100 terminals.

A standard transformer terminal for 110 000 volt service, having a creepage surface along the casing of 49 inches, was tested for one minute at each of the following voltages with only sufficient interval between tests to raise the voltage: 300 000 volts, 325 000 volts, 350 000 volts, 375 000 volts. The terminal then flashed over instantly at 400 000 volts. As there was considerable power behind the testing apparatus some small pieces were blown off the outer surface of the micarta casing, but the terminal easily withstood 375 000 volts for one minute as soon as the voltage could be reapplied. During these tests there was an entire absence of any static discharges or corona on the insulating parts of the terminal until it flashed over at 400 000 volts.

Later developments have shown that the use of a larger static shield (one of 9 inches diameter was used) would probably permit of testing this terminal at 400 000 volts without flashover as none of the insulation on the condenser proper was punctured.

The condenser terminal was used on the first outdoor apparatus actually put into commercial service at 100 000 volts. It was early appreciated that the uniformly distributed static field along its surface would materially increase the effectiveness of porcelain petticoats used on such apparatus when subjected to high voltage tests under a spray of water. Early experiments with metal shields connected electrically to the metallic layers of the condenser gave remarkable results under a spray. Terminals with numerous rain shields of earthenware were actually put into service at 100 000 volts and never failed from lack of ability to withstand line voltage under any condition of weather. Metal bells were, however, never put into service, because they would fail under melting snow if the snow contained any deposits of soot or dust. The earthenware shields proved unsatisfactory during frosty weather, as the glaze fell off, allowing moisture to penetrate the body of the shields and crack them when freezing weather returned.

At present all condenser terminals for outdoor service are covered with a series of porcelain rain shields cemented together so as to form a watertight tube. The inside of this tube is filled with the same compound as is used on the indoor terminals inside the micarta casing. The spacing between petticoats on all the terminals shown in the illustrations is 4⅛ inches approximately. From this an idea of the dimensions can be obtained. The surface distance on the 110 000 volt terminals is ten inches per rain shield. A smaller number of shields of larger diameter would serve the same purpose, but they would be fragile and harder to obtain with any degree of uniformity as to size and freedom from warping.

The behavior of these terminals under a spray test is remarkable and has to be seen to be fully appreciated. The transformer terminal for 110 000 volt service, Fig. 6, flashes over under spray, Fig. 7, at 270 000 volts approximately and will withstand indefinitely 220 000 volts under a spray of 0.2 to 0.5 inches per minute with a very small amount of corona discharge and a total absence of the detonating discharges which are generally noticed during similar tests on other apparatus.

The roof entrance shown in Fig. 8 *a, b* and *c* carries more than the standard number of rain shields and is built for 120 000 volt service. It easily withstands tests of 325 000 volts dry and 275 000 volts under a spray. The flashover voltage is in excess of these values. The condenser has a central conductor two inches in diameter, has 30 insulating layers and an outside diameter of 6.64 inches. The central portion is covered with a long tube of galvanized cast iron extended at one portion into a flange. The cast iron tube will allow considerable snow to accumulate on a roof without reaching the porcelains. The use of expensive conical cement structures, which are used with other forms of entrances, therefore becomes unnecessary, and a much smaller diameter of hole in the roof is required. As the cement structures required for the ordinary entrances are expensive and difficult to make watertight it has been found that the condenser type is as economical when installed as the ordinary type, although the terminal itself costs more.

No other terminals now commercially obtainable can be tested at so high a voltage without exhibiting violent corona discharges. Terminals have been built for outdoor service (Fig. 9) at 150 000 volts. These were tested at 300 000 volts under spray and at 375 000 volts dry. The flashover voltages are considerably higher and there was no evidence of distress at these tests. No other terminals have ever been made that will stand so high a test under a spray without any signs of distress.

The terminal shown in Fig. 11 is the strongest dielectrically that has ever been constructed. It has a creepage surface from flange to static shield of 80 inches; the diameter of the central conductor is 5.86 inches and the diameter of the outside of condenser is 21.37 inches. This terminal will give service continuously at a potential difference between central conductor and flange of 360 000 volts and will be entirely free from corona discharge on the insulating surfaces at this voltage. It is easily capable of giving service for five minutes at 500 000 volts without showing any corona discharge. Although it has never been flashed over, it is probable that the voltage required to do so would be not less than 750 000 volts. Smaller terminals constructed on similar principles, with large static shields, flashover from the edge of the static shield to the transformer cover, and it is probable that this terminal would flashover in the same manner.

Figs. 12 and 13 show a total of 346 condenser terminals, with their flanges and other fittings, all in process of preparation for shipment. The smallest terminals shown are on the inside of the rack at the extreme right (Fig. 12) and are for service at 44 000 volts. The large terminals lying on the floor in the foreground (Fig. 13) are for service at 150 000 volts. The large terminal with the ladder resting against it is the same as shown in Fig. 11. The high terminals with porcelain bells are all for roof entrances. Those at the right are for service at 110 000 volts and are standard size. Those at the left are the same as those shown in Fig. 8 *a, b* and *c*, and are made slightly higher than the standard in order that they will not flash over under a spray at 275 000 volts.

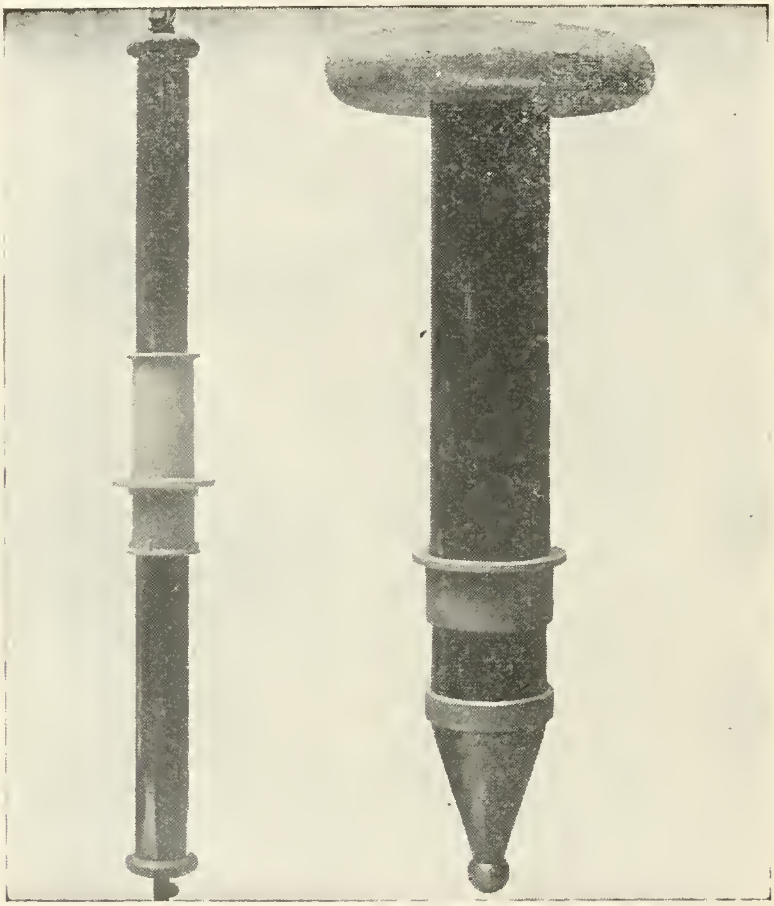

FIG. 10 FIG. 11

FIG. 10—110 000 VOLT INDOOR COMPARTMENT BUSHING

Intended for service through compartment walls or floors where both ends are indoors. The diameter of the condenser proper is 6.5 inches, but a 9.25-inch hole is required to admit the static shield and the flanges.

FIG. 11—TERMINAL FOR 360 000 VOLT TESTING TRANSFORMER

This terminal is about one and one-half as large as the one shown in Fig. 10.

Since 1908, when less than 100 terminals were manufactured for commercial service, the demand for this class of apparatus has increased until at present an equipment capable of manufacturing 1 200 terminals annually for voltages of 88 000 volts and upward is kept running to its full capacity. Wtihin a year the number of special machines required for making the large number of terminals has been quadrupled and the actual increase in capacity is about eight times that obtainable a year ago. In addition to the larger terminals, an equal number is being turned out each year for voltages of 44 000 and 66 000 volts. These smaller terminals do not require the same special machinery as the larger ones, although they are made by a similar process. During a period of over one year the manufacture of these terminals was carried on without a single failure during tests.

Only those who have witnessed the actual testing of condenser terminals can have a thorough appreciation of the entire absence of corona discharge at the guaranteed test voltages. The ordinary types of terminal will begin to show corona at that part passing through the flange. The corona discharges will gradually increase in length as the voltage is raised until the whole flashes over at a voltage usually not much in excess of that at which the corona streamers first appear. Increase in the length of the ordinary type of terminal without increasing the diameter at the flange, or increasing the creepage surface by the use of corrugations, or various form of projecting ribs or petticoats, without changing the diameter at the flange, will have little effect in increasing the voltage at which final flashover occurs. In the condenser terminal an increase

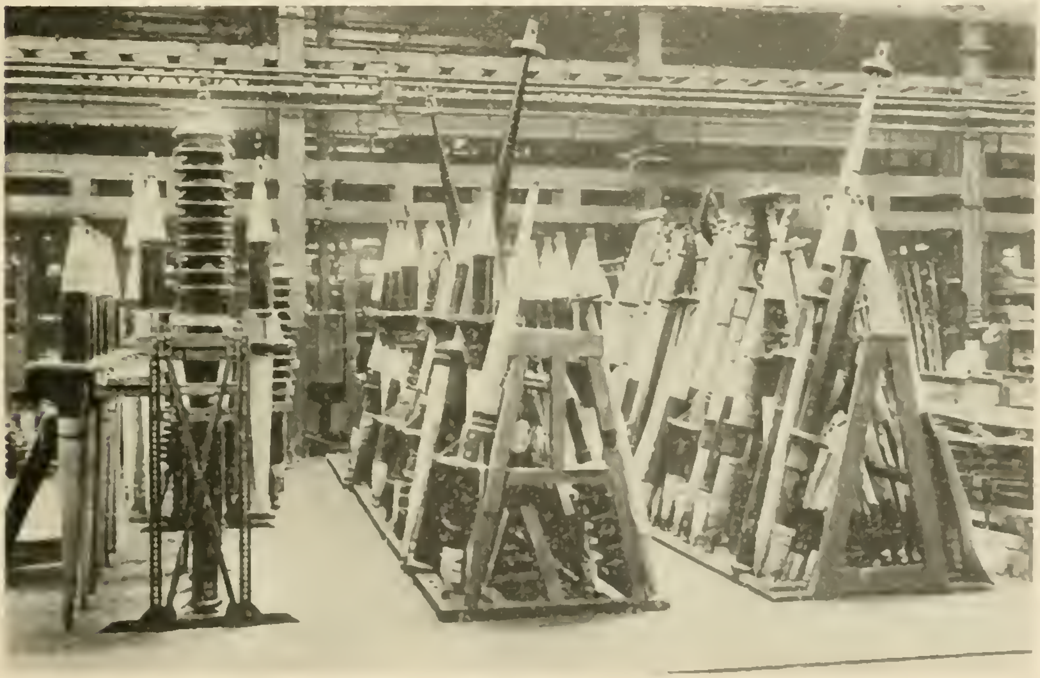

FIG. 12—TERMINALS IN VARIOUS STAGES OF ASSEMBLY

of length, independent of other changes in diameter or shape of flange, will increase the flashover voltage almost in direct proportion, if the diameter of the static shield is sufficient to prevent corona streamers from forming at the central conductor and extending toward the part of greatest diameter. If a condenser terminal is tested without static shield and without the cylindrical casing of micarta, it will be found that the corona streamers form first at its tip instead of at the flange as is the case with the ordinary type of terminal. The use of the static shield and the compound filled cylindrical casing prevents this formation, and when the terminal breaks down it does so without previous warning, much in the same manner as does a spark-gap between large spheres.

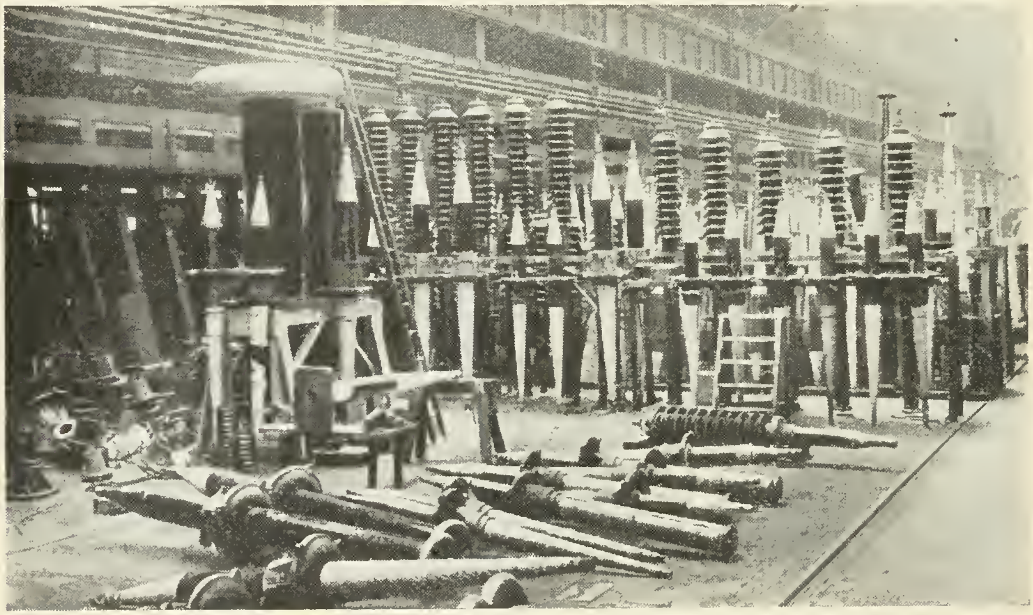

FIG. 13—CONDENSER TERMINALS, BOTH OUTDOOR AND INDOOR TYPES, BEING ASSEMBLED

The small diameter of these terminals is of great advantage, as sufficient space in the covers of apparatus remains for apertures of sufficient size that the tank may be entered and examinations made without removing the terminals.

It may be seen from the illustrations that, where one end of the terminal is used under oil, the tapered portion is relatively short. In the application of these terminals, the outer metallic band projects beneath the surface of the oil and, as it is at ground potential, there is an entire absence of corona formation in that part of the tank above the oil and a consequent freedom from danger of ignition of the oil vapors. When the ordinary type of terminal is tested with one end immersed in oil, considerable disturbance at the surface of the oil takes place, due to the oil being expelled by the force of the static field. This disturbance is entirely absent when testing a condenser type terminal.

In order to reduce the surface stress at the flange, on the ordinary type of terminal, frequently large panels of insulating material are placed in the covers of apparatus to reduce the surface intensity. Sometimes the entire cover is made of insulating material. All of the insulating materials available for this purpose are either inflammable or too fragile to resist the internal pressures sometimes experienced in operating transformers and circuit breakers. In the case of a condenser terminal, the surface intensity at the part passing through the flange is the same regardless of the voltage, since by design the stress for the individual condensers is kept at a constant quantity. That is, the number of condensers used is directly proportional to the service voltage. The stresses are actually so low that, as has been previously stated, there are no corona discharges at this portion until flashover voltage is reached. This result is accomplished with a remarkably small diameter of flange aperture, as the dimensions given in this article plainly show

After installation, the condenser terminal can operate indefinitely without attention except to see that it is not actually subjected to leaks from a roof and that the oil is at a proper level in the tanks where it is applied. Terminals designed for indoor service are much lighter in weight than other types and are therefore more easily installed.

From the foregoing it will be apparent that the condenser type terminal occupies small space, is easy to install and has very high dielectric strength. Its record in commercial service has proved that it is exceedingly reliable for both indoor and outdoor service without attention after installation.

RECENT DEVELOPMENTS IN OIL CIRCUIT BREAKERS

J. N. MAHONEY

AN UNUSUAL amount of time and money have recently been spent in research and development work by circuit breaker manufacturers, and especially by the organization with which the writer is connected. This has been found advisable on account of the unusually high voltages, high capacities and length of lines, which are now becoming common. Extensive tests have been made under service conditions to demonstrate the efficiency of these improvements.*

GENERAL POINTS OF DESIGN

In an oil circuit breaker there are three qualifications necessary. First, it must be insulated for the voltage at which it is rated; second, it must have sufficient carrying capacity for its rated current; third, it must have sufficient circuit breaking capacity to meet the conditions at the point where it is applied and to suit the character of the service.

Assuming that the first two qualifications have been met in the product of well-known manufacturers, at least on apparatus up to voltages that have been standard for some years, the greatest necessity for improvement was to meet the third qualification under the new conditions. Considerable improvement is also shown in contact details and insulation, mainly from the point of view of decreased maintenance expense.

Breaking Capacity—Oil breakers are made in a variety of types and sizes for various circuit breaking capacities, varying from a switch capable of operating in connection with a plant of but a few hundred kilowatts, to those for service on systems of several hundred thousand kilowatts capacity. The breaking capacity, or as it is variously stated, the ultimate breaking capacity or rupturing capacity, usually takes into consideration only the k.v.a. capacity of the generating or synchronous apparatus that may supply the circuit breaker in event of a short-circuit. Another factor is the consideration of the inherent reactance and characteristics of apparatus connected to the circuit which tend to reduce the short-circuit current. Other factors are the speed of operating characteristics of the circuit breaker mechanism itself; the relation of the circuit breaker to the lines and apparatus in a particular system; and the method of tripping the breaker, or otherwise obtaining automatic operation. The detailed effect of these several factors on the application of the appropriate type of oil circuit breaker is too complicated to be included in the present discussion.

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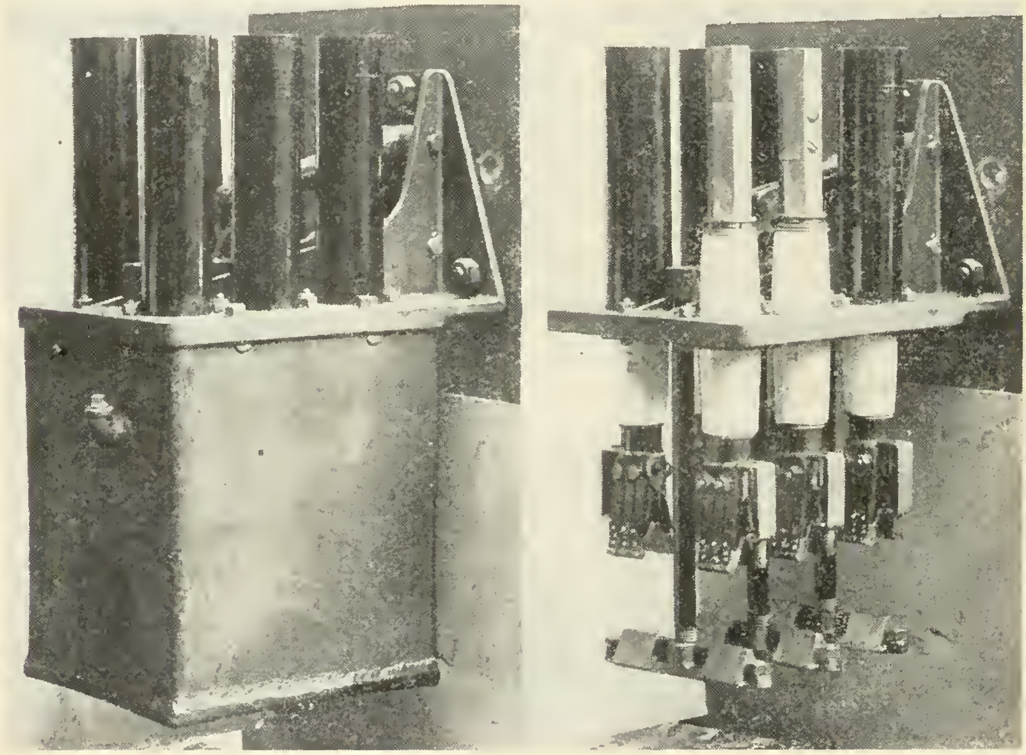
*See article by the author in the JOURNAL, September, 1912, p. 739.

OIL CIRCUIT BREAKER FUNCTIONS

When an oil circuit breaker is opened under load, an arc is formed between the stationary and movable contacts, the size of the arc depending on the amount of current. This arc persists until the first zero position of the voltage wave after the contacts have been separated far enough for the oil to break the arc. The heat of this arc disintegrates some of the oil surrounding the contacts, forming a gas bubble. The size of the arc and of the resultant gas bubble depends upon the current flowing at the instant of separation and the duration of the arc. The ability of the gas bubble to rise far enough so that the arc will be quenched during the zero point of the wave is controlled by the specific gravity of the gas bubble in relation to the head and volume of oil and the viscosity of the oil. Oil having high specific gravity, sufficient head and low viscosity will have enough pressure to force the bubble up away from the contacts, irrespective of their positions. The relation of the horizontal surface of the oil to the cross-sectional area of the contact and terminal arrangements will also determine the ease with which the gas bubble will clear itself of the contacts. If there is a reasonable space for oil around the contacts and terminals, the pressure of the head of oil will force the bubble out into the free oil space and up to the gas chamber.

A well designed oil circuit breaker should have a good depth of oil of good quality in order to displace the gas bubbles as rapidly as possible. This requires a considerable head of oil above the break so that its pressure will displace the bubble, as already explained, and a considerable depth of oil below the break in order to permit the arc and bubble to be formed in a mass of clean oil. In order to keep the oil from being ejected from the tanks due to the great disturbances of a short-circuit, it is necessary to close the tanks almost completely. The pressure due to the gas formed by the arc, and to other disturbances incident to opening under short-circuit, are almost equivalent to those of an explosion, and for this reason the tanks must be built exceptionally strong and the terminal insulating details fastened to the frame in a very substantial manner.

In order to minimize gas pressure, a gas chamber of considerable size is provided above the oil level and arranged with an outlet that will offer free passage to the gas but will baffle the ejection of oil. Thus, when the bubble is formed it will displace some of the oil which will rise to this gas chamber. Then when the oil displaces the gas bubble, the bubble will rise into this space. Also, the gas above the oil, being easily compressed, will act as a cushion and will tend to absorb the shock of the break. The greater the volume of this gas cushion, the better the cushion effect.



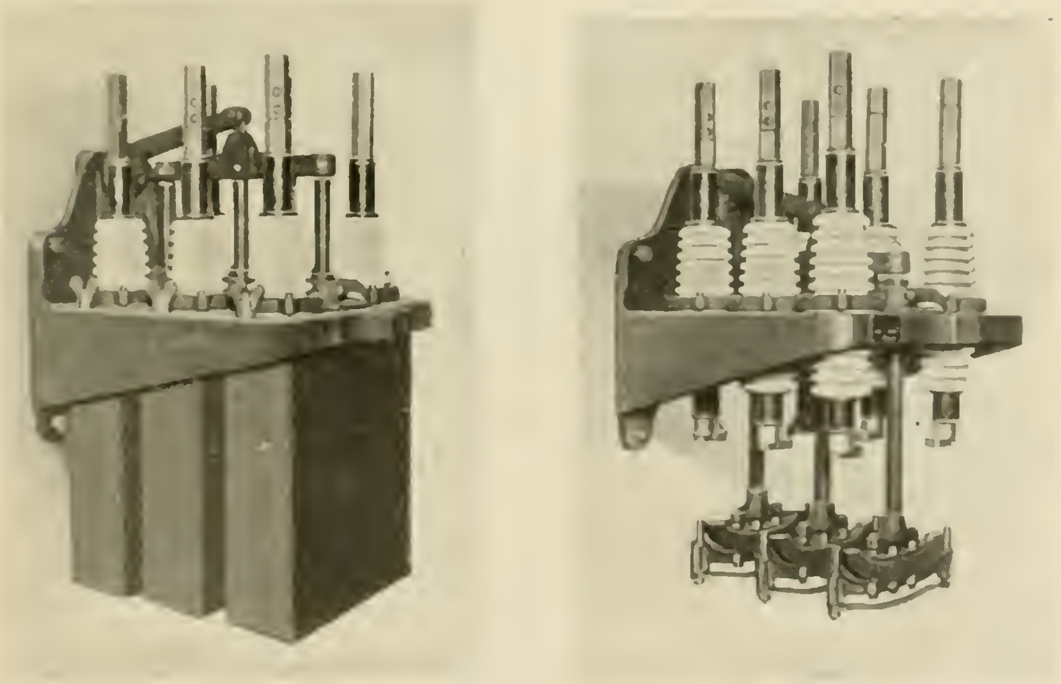
FIGS. 1 AND 2—7 500 VOLT, 500 AMPERE, THREE-POLE, OIL CIRCUIT BREAKER FOR WALL OR SWITCHBOARD MOUNTING

Showing switch complete, and also partly dismantled to give a view of the details of the operating mechanism.

The arrangement of butt arcing tips should take into consideration the magnetic blow-out effect caused by the current passing down through the contact stud, across the contacts and up the opposite stud. This tends to blow the arc outward from the center away from the main contact and off the outer edge of the butt arcing tips. This action, together with the gravity or buoyancy action of the arc gasses causes the arc gasses to be rapidly driven outward and upward away from the contacts and supporting bushing, and to assist the successful operation of the circuit breaker under short-circuit conditions.

OPERATING MECHANISM

Except in circuit breakers of the switchboard type, a combined accelerating and dashpot device have formed one of the principal recent improvements in circuit-breaker equipment. This consists of a cylinder having a piston for the dashpot action, which is in turn acted upon by a powerful spring for the accelerating function. The spring comes into action as soon as the circuit breaker is tripped, rapidly separating the contacts. The dashpot acts at the finish of the circuit breaker travel, bringing the moving parts to rest without excessive shock. The combined accelerating and dashpot cylinder is a unit in itself and is mounted on the operating lever of the magnet mechanism in the electrically operated types, and on one of the bell-crank brackets in the mechanical remote control types. The use of this accelerating mechanism is necessary in high-powered circuit breaker work in order to secure positive action under conditions of short-circuit



FIGS. 3 AND 4—25,000 VOLT, 600 AMPERE, THREE-POLE OIL CIRCUIT BREAKER, FOR SWITCHBOARD OR REMOTE MECHANICAL CONTROL.

Showing switch complete, except for the sleeves over the leads, and also with cases removed.

which cause high pressure in the tanks. Such a pressure, acting on the contact-carrying rods without this mechanism, has been known to prevent the movable contacts from traveling more than a short distance away from the stationary contacts, or has made the action of these contacts in opening very slow, and has caused the arc to persist in the oil for a length of time sufficient to generate a pressure in the circuit breaker strong enough to disable it.

In addition to this accelerating device, to assist the action of gravity in tripping the circuit breaker, the diameter of the wood rods which carry the contacts has been reduced or a steel rod has been substituted at the point where the piston action occurs. The steel rod is of much smaller diameter than a correspondingly strong rod of wood or other fibrous material and presents a small area for the pressure to act on, therefore making the action of the switch more positive.

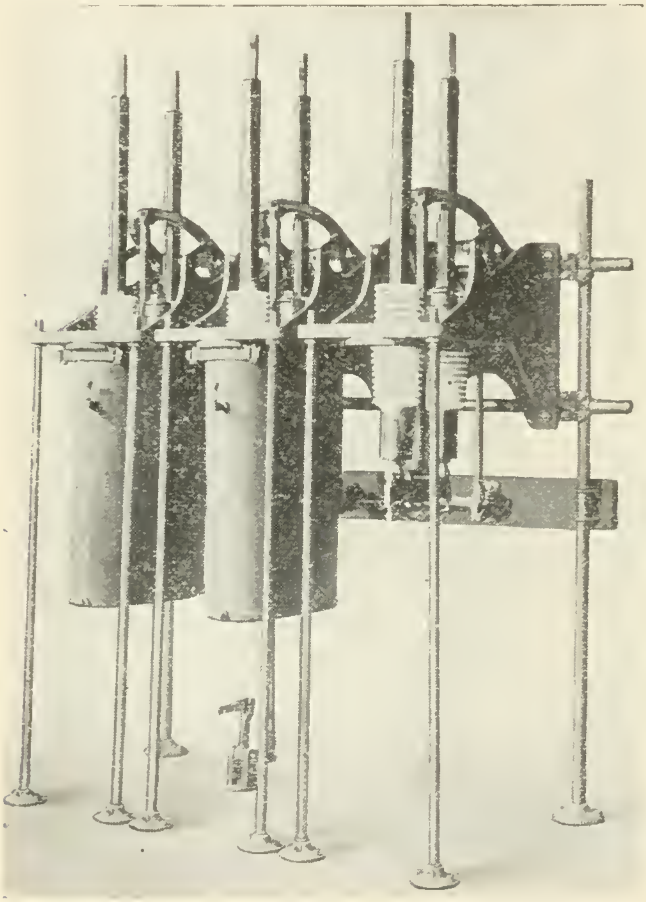


FIG. 5—35 000 VOLT, 600 AMPERE, THREE-POLE OIL CIRCUIT BREAKER

Pipe mounted for remote control

The self-contained electric operating mechanism shown in Figs. 6, 10, 11, 12 and 15 consists of a closing solenoid with proper levers and latch and a direct current tripping solenoid for releasing the latch. The closing plunger is provided with a piston packing for obtaining a dashpot action during the closing operation and with an automatic valve of simple form to permit the plunger to retrieve quickly in tripping the circuit breaker. A means is provided for inserting a lever, when desired, for closing by hand.

OIL CIRCUIT BREAKERS OF MODERATE CAPACITY AND VOLTAGE

Figs. 1 and 2 illustrate a type of circuit breaker which is made in switchboard or remote mechanical control mounting and hand or electrically operated types for moderate voltages and moderate capacities. The contacts have been improved by supporting the conducting tip on the end of the contact fingers, which engage the moving contact wedged surface, on the end of a thin steel spring, permitting the contact to align itself automatically. This spring is shunted by a liberal copper leaf shunt to conduct the current from the finger tip to the terminal stud. The contact pressure is obtained by a second and heavier steel spring provided on its end with a head which applies the pressure over the center of the contact tip of the finger. Several fingers are used per stud according to the capacity of the breaker. The initial position and contact pressure of the several fingers is determined by a steel stop mounted on the contact stud between the two sets of fingers. The stop determines the opening between the fingers into which the wedge enters and prevents the play of the moving contacts from causing trouble by allowing considerable latitude for the wedge to enter between the fingers. A plunger arcing tip, provided as a part of the stationary contact details, makes a butt contact engagement with a brass cap bolt screwed into the moving contact cross bar. This butt arcing tip maintains contact for a considerable distance after the main contact fingers and moving contact wedge have left contact, the

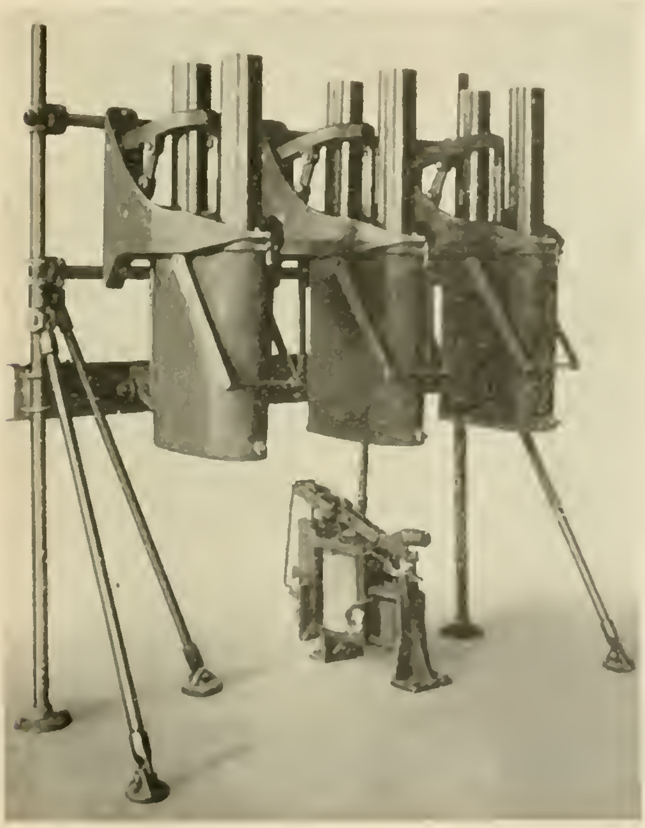
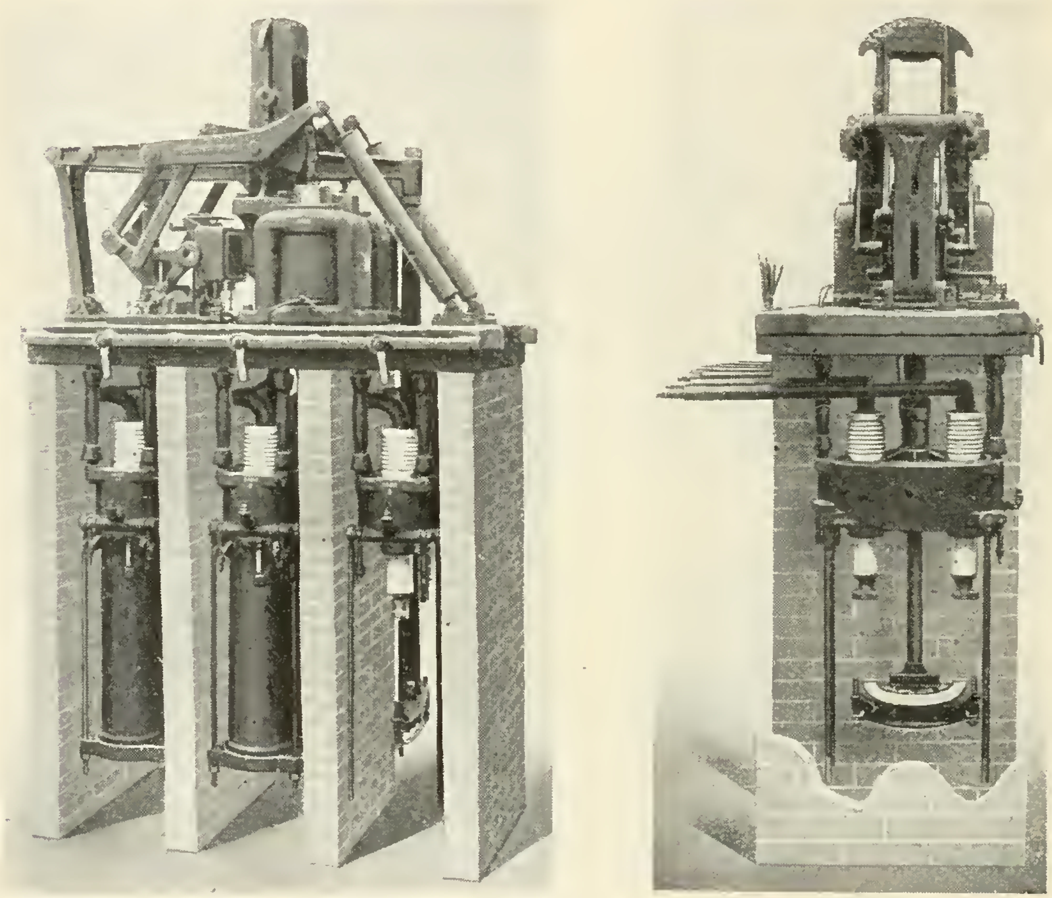


FIG. 6—7 500 VOLT, 1 200 AMPERE, THREE-POLE OIL CIRCUIT BREAKER

Pipe mounted and equipped for electrical remote control.

distance being predetermined by the stop between fingers. This is an improvement on the older forms of contact in which no stop or separate arcing tip on both members was provided.

The general mechanical design is unusually rugged. The oil tank is of heavy steel plate. It has lap-welded joints with the bottom flanged and welded on the outside of the tank sides, and a flange on the supporting frame of the circuit breaker encloses the upper end to restrain it from distorting under internal pressure. The lining of the tanks is of micarta with individual "micarta" sleeves for each pole of the breaker. The tanks are deep enough to provide a considerable air space above the oil level for expansion of the arc gasses, and to prevent the slopping of the oil from internal disturbance. The gasses are vented through the clearance around the operating wood rods of the frame. The contacts and contact details are



FIGS. 7 AND 8—FRONT AND SIDE VIEWS OF 15 000 VOLT, 600 AMPERE OIL CIRCUIT BREAKER OF THE CELL MOUNTING TYPE

Equipped for remote electrical control.

supported by vertical porcelain pillars which are clamped in position. This is true also of the conducting stud and contact details to the porcelain pillar, so that no babbitt or cement is used in the construction. Lock washers are used on the clamp bolts and conducting stud to hold same in position and prevent loosening from the vibration and hammer blows that occur in the operation of the circuit breaker. The pillars above the frame together with the exposed terminal, are provided with a moisture proof micarta tube to overcome possibility of accident where the exposed live terminals are not otherwise insulated. This line of circuit breakers is made in capacities up to 800 amperes and up to 15 000 volts.

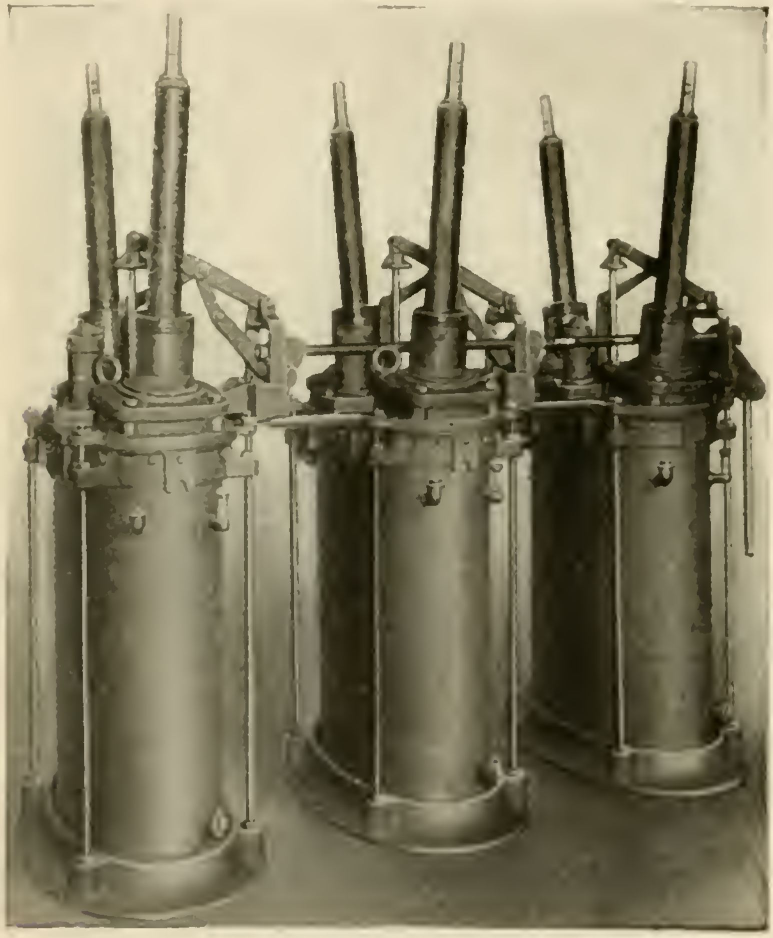


FIG. 9—11 000 TO 44 000 VOLT, 300 OR 600 AMPERE, THREE-POLE OIL CIRCUIT BREAKER

Floor mounting type. Can be equipped with mechanical or electrical remote control

HIGH CAPACITY, SELF-CONTAINED, MULTIPOLAR OIL CIRCUIT BREAKERS

A development of medium voltage, high capacity oil circuit breakers is shown in Figs. 3 and 4 in which the poles of the circuit breaker are all mounted on one metal frame which can be supported on a wall or other frame work complete with its electric operating mechanism, or operated mechanically by a regular remote mechanical control mechanism.

In this line of circuit breakers and the several types hereinafter mentioned, above 300 amperes capacity, the contacts are what are known as the butt type, laminated brush, with butt type solid arcing tips. The butt type laminated brush contact is the same that is used in all modern high class carbon circuit breakers. This form of main contact has a very high contact pressure, usually around 100 pounds per square inch, and is designed to be automatically self-cleaning at the contact surface. Both the high contact pressure and the wiping action contribute to the self-cleaning feature in a degree not obtained by any other form of contact. All the pressure on the surfaces of both the main and arcing contacts tends to throw the contacts apart, or, in other words, open the switch.

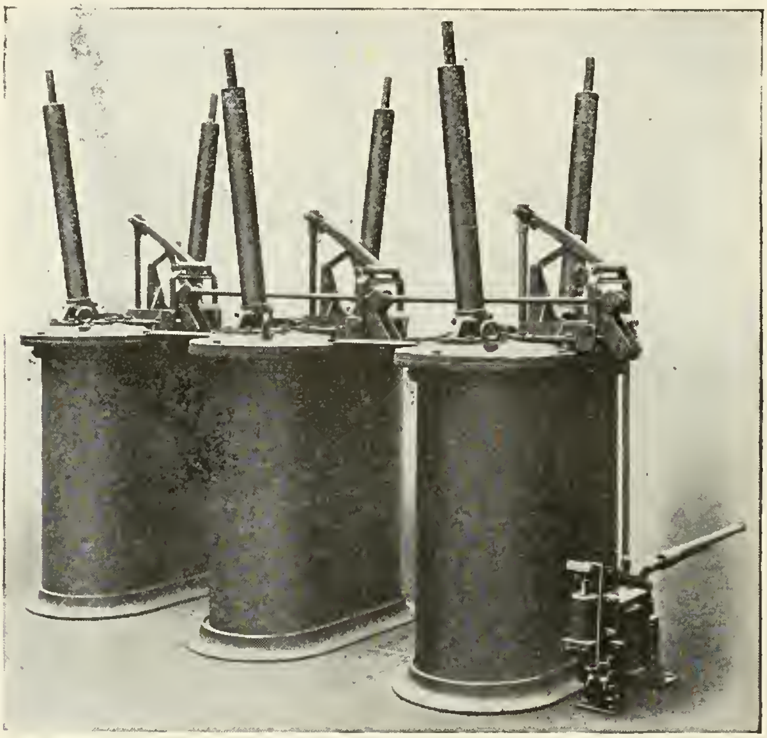


FIG. 10—66 000 VOLT, 300 OR 600 AMPERE, THREE-POLE OIL CIRCUIT BREAKER

Floor mounting type, equipped for electrical remote control. A lever is provided for hand closing.

A separate tank is used for each pole of the circuit breaker. The mechanical details are made very rugged to withstand the high internal pressures due to opening heavy short-circuits. The porcelain insulating details for supporting the contacts are of the pillar type substantially clamped in position, and the contact details are in turn clamped to the porcelain pillars, so that repairs or replacement may be made conveniently. The range of capacities is from 300 to 2 000 amperes, and up to 25 000 volts.

HIGH CAPACITY, UNIT FRAME, PIPE MOUNTING CIRCUIT BREAKERS

Another recent development is a complete line of circuit breakers intended for mounting on pipe or structural frame work, or on the wall without the necessity of enclosing structures. They can, however, be mounted in structures if so desired. If the structure is used, each pole can be mounted in a separate cell or several poles can be mounted collectively with the operating mechanism in a single cell, thus segregating the complete unit from other similar units. The latter is the preferable type of structure mounting. This form of circuit breaker,

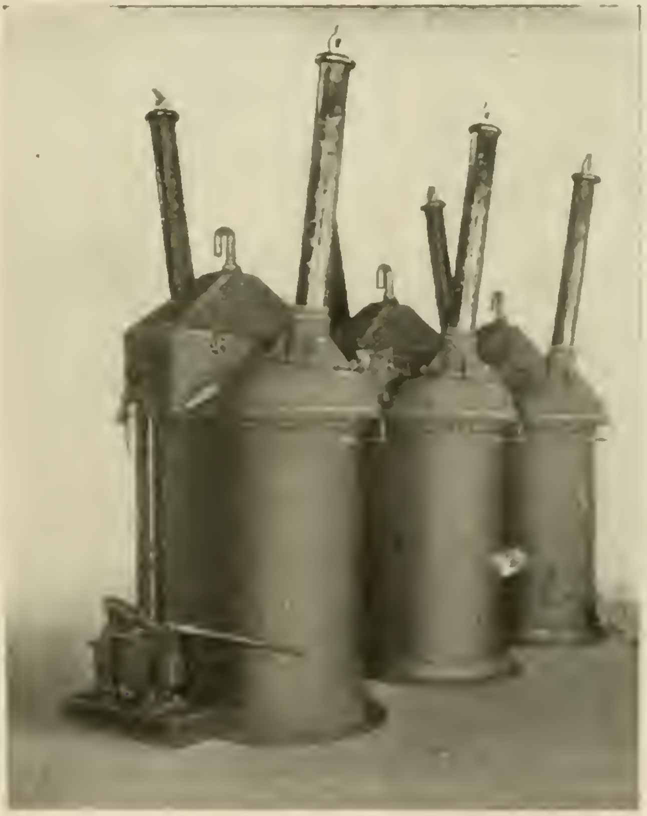


FIG. 11—120 000 VOLT, 300 AMPERE, THREE-POLE OIL CIRCUIT BREAKER

Floor mounting type, equipped for electrical remote control, or for emergency hand operation.

illustrated in Figs. 5 and 6, is made in two frame sizes, in capacities up to 3 000 amperes, 15 000 volts, up to 1 200 amperes at 25 000 volts, and up to 600 amperes at 35 000 volts.

In this, and in the larger types of circuit breakers described later, an elliptical form of tank is used, having no flat surface, except at the bottom. The pressure within the tank is restrained by the metal under tension, as in steam boiler practice, and not in deflection, as with the rectangular tank. The metal in these elliptical tanks is one-tenth to one-eighth inches in thickness. All of the joints are lap-welded and the bottom is flanged outside of the tank proper, and lap welded thereto. This form of construction causes the pressure within the tank to place counteracting tension stresses in the bottom to balance the deflecting stresses caused by the pressure directly acting on the bottom. The supporting frame for the tank is made to enclose the tank flange in such a manner as to keep the tank from spreading

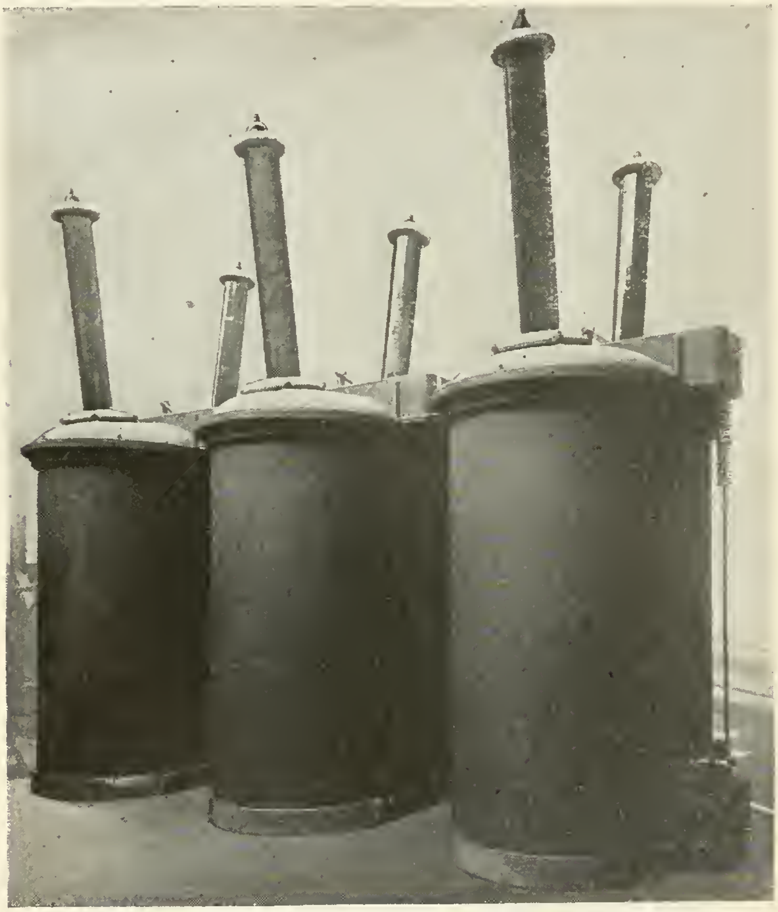


FIG. 12—165 000 VOLT, 300 AMPERE, THREE-POLE OIL CIRCUIT BREAKER

With operating mechanisms removed. Type used the Pacific Light & Power Corporation.

when under pressure from the gases of a short-circuit. Sufficient air space is provided above the oil, either in the tank chamber or a chamber in the supporting frame, to take care of the gasses caused by arcs and to reduce the pressure in the tank. A baffled vent fitting is provided for the escape of gasses.

HIGH CAPACITY, MEDIUM VOLTAGE, CELL MOUNTING, CIRCUIT BREAKERS

A well known line of oil circuit breakers in which all of these improvements have been incorporated, is shown in Figs. 7 and 8. This line is particularly designed for cell structure mounting for voltages up to 22 000. A special feature of this line is the use of a distinctive type of mechanism above the tanks for operating the three poles as a unit. The use of auxiliary tie rods and supporting castings on the tanks is also shown. These increase the ability of the tank to withstand excessive pressure.

FLOOR MOUNTING TYPE OF HIGH VOLTAGE, HIGH CAPACITY CIRCUIT BREAKERS

It has become quite common to make circuit breaker installations in high voltage and high capacity work, without any form of circuit breaker structure. The breakers are usually of single-pole units mounted on the floor or gallery and operated through either remote hand or electrically controlled mechanism by which any number of units can be coupled to make a breaker of the usual number of poles. Circuit breakers of this type are illustrated in Figs. 9, 10, 11 and 12. With the exception of the type shown in Fig. 9 this line of circuit breakers is equipped with the condenser type terminal.

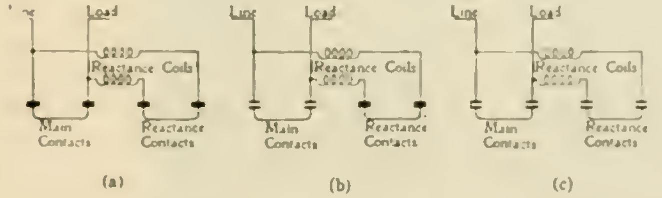


FIG. 13.—SCHEMATIC DIAGRAM OF REACTANCE TYPE OIL CIRCUIT BREAKER

REACTANCE TYPE CIRCUIT BREAKERS

To limit the disturbance in the circuit breaker and on the line, where extremely large powers at high voltages must be controlled with certainty under all conditions, a type of circuit breaker has been developed in which a reactance is cut into the circuit before the main contacts open.

These breakers have two sets of contacts per pole included in and operated by the same mechanism. One of these sets is connected through the reactance and the other serves to short-circuit this reactance when the circuit breaker is completely closed, as shown in Fig. 13. When the circuit breaker opens, these last contacts open first, shunting the circuit through the reactance in series with the other contacts. The reactance contacts then open immediately, breaking the entire circuit.

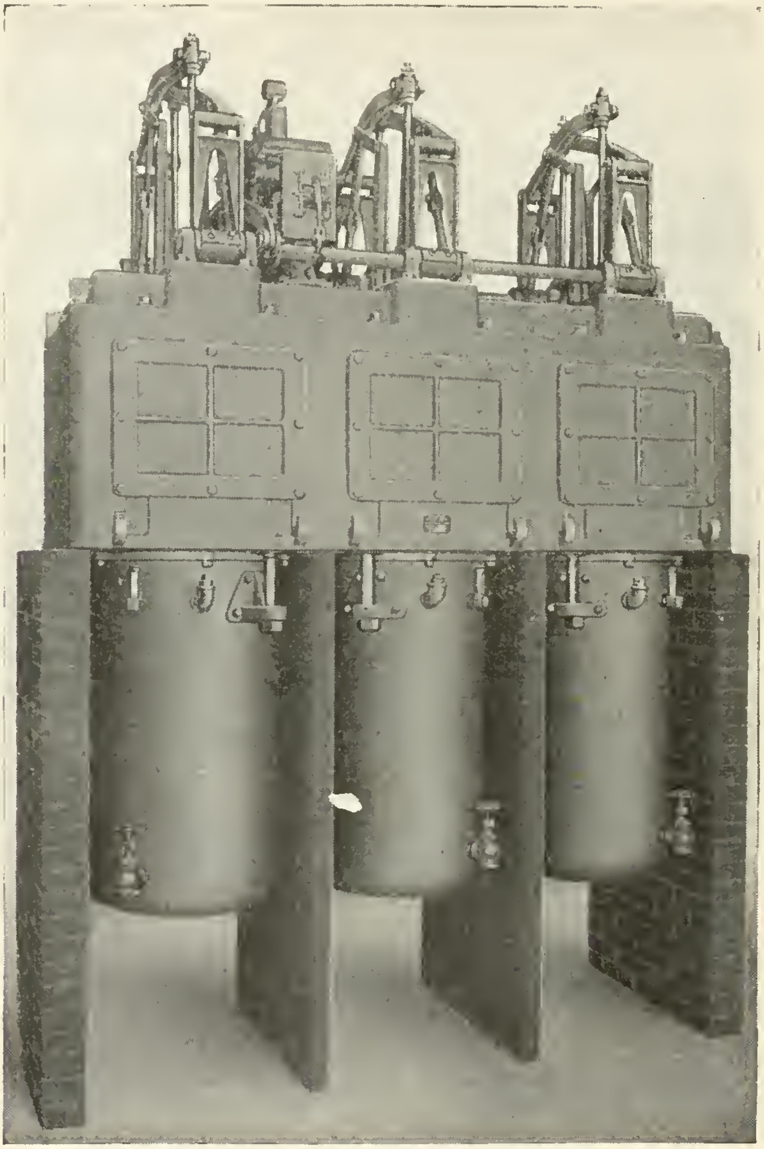


FIG. 14—25 000 VOLT, 1 200 AMPERE, THREE-POLE, REACTANCE TYPE CIRCUIT BREAKER

Cell Mounting type.
Arranged for electrical remote control.

The action of cutting the reactance into the circuit as an intermediate step limits the flow of current under short-circuit conditions and absorbs the inertia and stored energy of the system, making the break on the final pair of contacts comparatively light, and reducing surges in the circuit. At the same time the smaller current at the final break reduces the possibility of voltage rise.

This reactance feature makes this type of circuit breaker particularly suitable for automatic operation on feeder distributing systems connected directly to the bus-bars of high power generators, this being the most severe condition to be met. These circuit breakers are illustrated in Figs. 14 and 15. The single piece cylindrical steel tank gives them unusual mechanical strength.

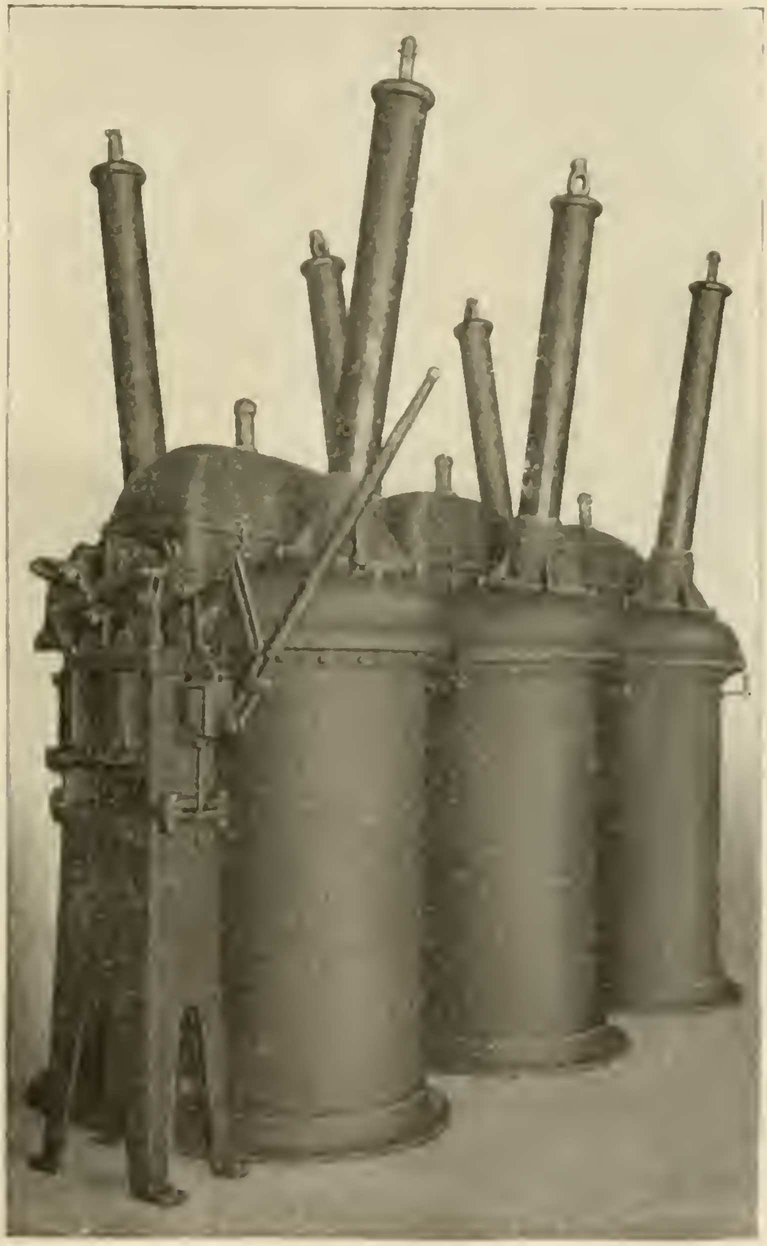


FIG. 15—110 000 VOLT, 600 AMPERE, THREE-POLE REACTANCE TYPE CIRCUIT BREAKER

Floor mounting type. Equipped for electrical remote control.

ELECTROLYTIC LIGHTNING ARRESTERS

G. C. DILL

THE ideal lightning arrester is one which affords instantaneous relief from abnormal voltages, but which prevents the flow of dynamic current after the abnormal voltage has been relieved, and which produces no disturbance on the line on which it operates. This may be more clearly understood by the analogy of the steam safety valve, and the hydraulic relief valve. These appliances permit no flow of steam or water at normal pressures, but when the pressure rises above the normal value the valve opens and permits the excess pressure to be relieved, after which the valve closes and further flow of steam or water is prevented. The ideal lightning arrester is more nearly approached in the electrolytic arrester than in any other arrester which has yet been placed upon the market.

The effectiveness of the electrolytic lightning arrester, which has come into pretty general use for the protection of power circuits of above 2200 volts, is due to properties of aluminum plates which have suitable electrolyte between them, namely, the valve action and the condenser action. By virtue of the property which we have termed valve action, the arrester offers a very high resistance to current at voltages below certain critical values, and a very low resistance to voltages above these critical values. By virtue of the condenser action, the flow of current at low frequencies is small but at high frequencies it is considerable.

These two vital properties of the electrolytic arrester are due to the inherent characteristics of a film of aluminum hydroxide which has been deposited on the aluminum plates by electrolytic process. This film of aluminum hydroxide is very thin and its exact structure is not yet definitely known. As stated before, it offers a very high effective resistance to currents of moderate voltage, but when the voltage exceeds a critical value of approximately 320 to 340 volts for alternating current and 420 to 440 volts for direct current, the film breaks down in myriads of minute punctures. Voltages above the critical point are practically short circuited, very little resistance being interposed to retard the flow of current due to excess voltage. The discharge current is proportional to the superficial area of the aluminum plate exposed to the electrolyte. Thus if the exposed area of a plate is doubled, it will permit twice as much current to flow. When the excess voltage is relieved, the minute punctures seal up, the original resistance reasserts itself, and the flow of dynamic current is checked. Thus far the analogy to the safety valve is very close.

The film of aluminum hydroxide on the surface of the trays constitutes the dielectric of a condenser. This property is of considerable importance in the electrolytic arrester. The flow of current due to capacity varies inversely as the frequency of the current. At commercial frequencies the flow of current in the normal arrester due to the condenser action is small. Lightning discharges are, however, of very high frequencies, and with a discharge at a frequency of 10 000 cycles, the commercial arrester would permit a flow of something like 100 amperes.

When a voltage less than the critical voltage is impressed across an electrolytic arrester a small charging current flows, which, in the normal commercial arrester, is less than 0.8 ampere. It is composed of two components, the direct leakage through the film on the surface of the trays, and through the electrolyte, and the capacity current, these two components being at 90 degrees from each other. In an arrester in good condition the direct leakage is less than 0.02 ampere, while the remainder is capacity current: thus it will be seen the actual power used in the charging operation is very small. This flow of current would in time heat the cell of an electrolytic arrester, and to prevent this, horn gaps are inserted in the line between the electrolytic element of the arrester and the line to be protected. At normal voltages these gaps insulate the cells from the line but at excess voltages they arc over and permit a discharge to ground.

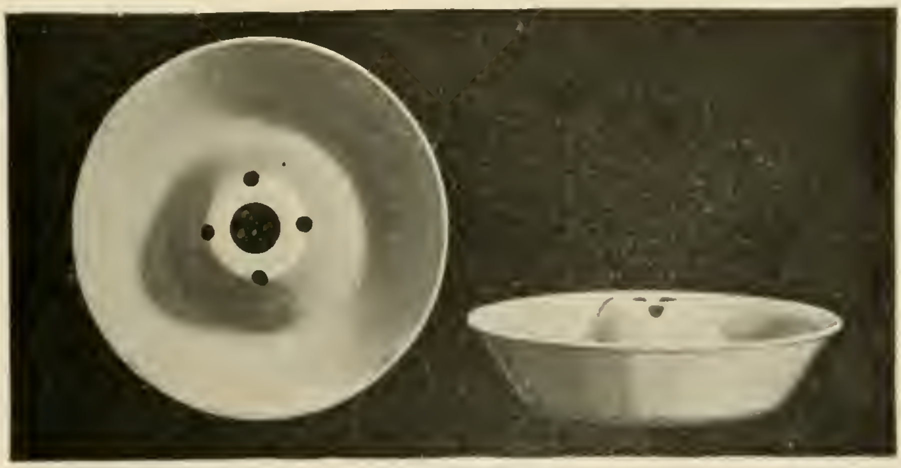


FIG. 1—ALUMINUM TRAYS USED IN ELECTROLYTIC ARRESTERS

In the commercial arrester the aluminum plates referred to take the form of trays such as shown in Fig. 1. These trays serve as receptacles to hold the electrolyte, the sloping sides permitting the escape of such gasses as may form during a discharge of the arrester. The film on their surface is formed by immersing the trays in a tank of electrolyte and passing current from one tray to the other. At first there is a heavy flow of current, but as the film builds up, the current decreases. The film gives the trays a dull grey appearance; if it is not well formed they present a slightly shiny appearance. The trays in the commercial arrester are stacked one on top of the other as shown in Figs. 2, 3, and 4, each one being separated from the other by porcelain spacers placed upon the periphery. In some makes of arresters, these trays are arranged in groups to permit greater ease in handling, (this arrangement is shown in Figs. 3 and 4) while in other makes no attempt is made at grouping them in sections. The number of trays which are placed in a stack depends upon the voltage of the line upon which the arrester is to operate. In practice there is usually one tray for each 290 volts, alternating current, or each 350 volts direct current, impressed across the cell. The assembled stacks are placed in suitable frames of solid construction, as shown in Fig. 5, which are placed in steel tanks to give mechanical protection. The oil in which they are immersed, as shown in Fig. 6, prevents evaporation of the electrolyte, increases the insulation from

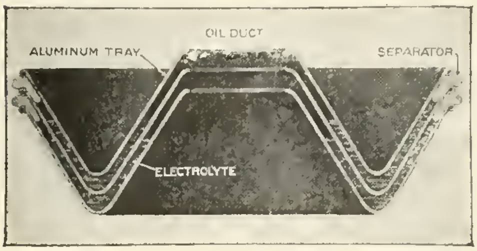


FIG. 2—CROSS-SECTION OF TRAYS SHOWING SPACERS

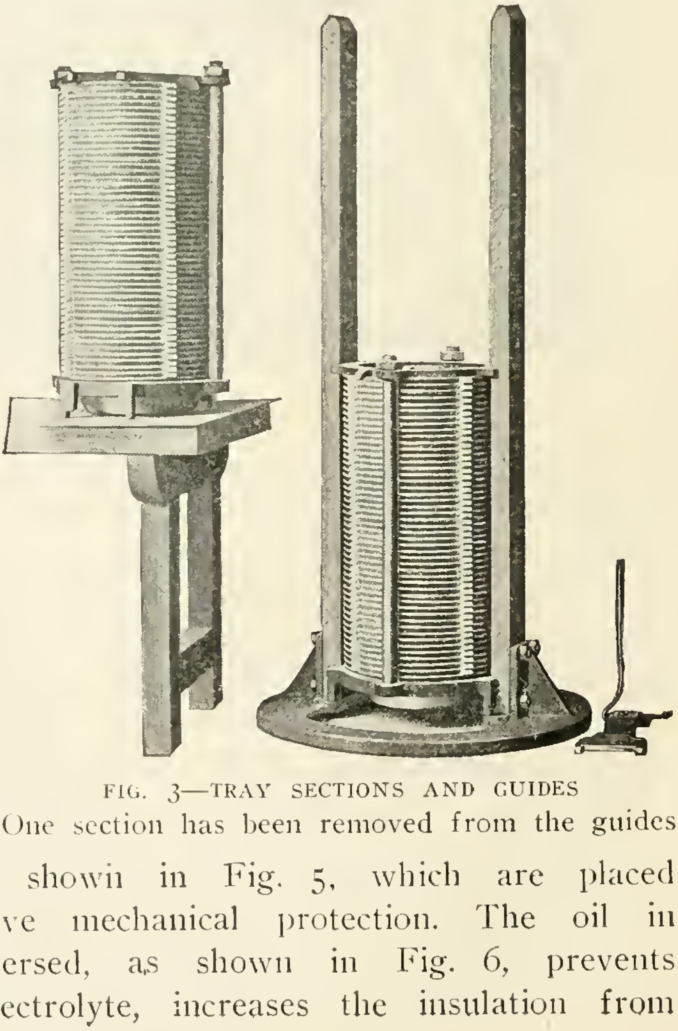


FIG. 3—TRAY SECTIONS AND GUIDES
One section has been removed from the guides

the trays to the tank, disposes of heat by convection, and also absorbs considerable quantities of heat. This property of oil is very essential because considerable quantities of heat may be developed during a discharge. The natural circulation is aided by the micarta barrier shown in Fig. 6, which also increases the insulation from the tray to the tank. The use of this barrier has made possible a decrease in the size of the arrester tanks, without decreasing the insulation and ability of the arrester to take care of a discharge.

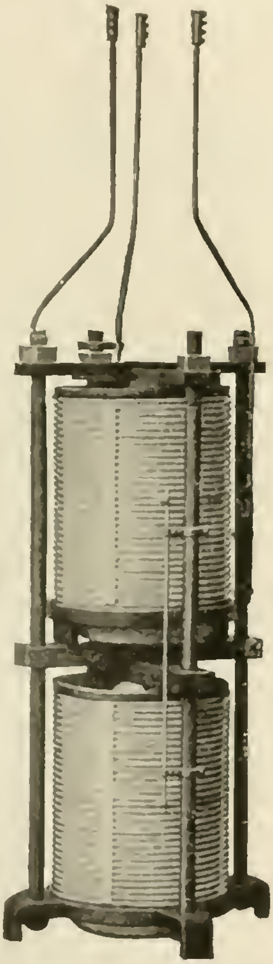


FIG 5—DESIGN OF TRAY STRUCTURE USED FOR VOLTAGES UP TO 13 500

This shows aluminum trays nested in wooden supporting frame for 6600-volt ungrounded neutral arrester

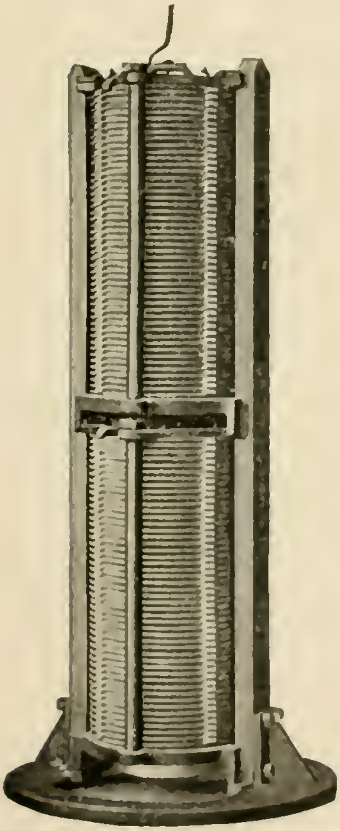


FIG. 4—TRAY SECTIONS IN GUIDES

Practically all electrolytic arresters are built for three phase systems. In their choice it is necessary to consider the voltage of the system, and whether the system has an ungrounded neutral, a grounded neutral, or whether the neutral is grounded through a resistance. Electrolytic arresters may now be had for all voltages up to 165 000 volts, three phase, grounded or ungrounded neutral circuits. From the standpoint of the lightning arrester, a system may be considered as having a grounded neutral, either when the neutral is solidly connected to the ground, or when the resistance between the neutral and ground is sufficiently low to permit sufficient current to flow to trip out the circuit breaker in case of either an arcing or a solid ground. In all other cases the system should, for lightning arrester purposes, be considered as having an ungrounded neutral. If any doubt exists the safe course is to consider the system as ungrounded.

The grounded neutral arrester has three phase sections. In the low voltage arrester, these are mounted in one tank, while in higher voltage arresters they are mounted in three separate tanks, mounted on some suitable solid foundation. These tanks should always be thoroughly grounded. The theoretical diagram of connections for this arrester is shown in Figs. 7 and 8, while the actual connections of the arrester are shown in Fig. 9. The ungrounded neutral arrester differs from the grounded neutral arrester in that it has a fourth or ground section connected between the common connection of the three phase section or the neutral point and the ground. The voltage relations are shown in Fig. 10; the theoretical connection is shown in Fig. 11, and the actual connections of a moderate voltage arrester are shown in Fig. 12. The phase sections of the arrester are usually designed to withstand the voltage between any line and neutral or approximately 58 percent of the line voltage. Suppose that in Fig. 7 the connection between neutral and ground did not exist, then if a ground should occur at some point on the line, the circuit breaker would not disconnect the line, and one of the phase sections would have full line voltage impressed across it, while it is designed to withstand only 58 percent of that voltage. This would, in the course of a little time, seriously heat the electrolyte, dissolve the film on the surface of the trays and might, in the course of a few hours, destroy the two phase sections unless there was a fuse placed in the line to protect them. To prevent this condition from occurring, a fourth or ground section is placed between neutral

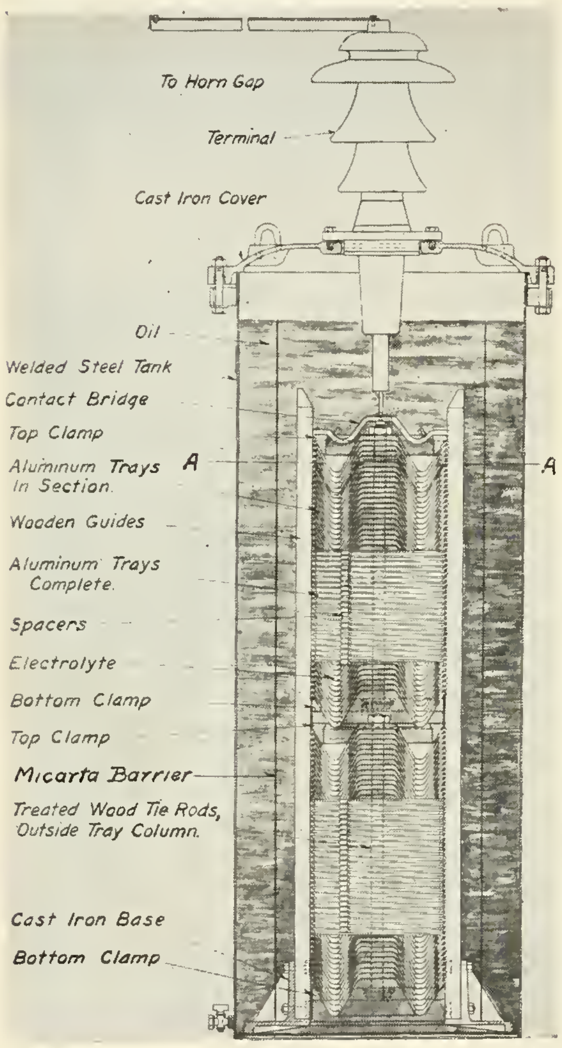


FIG 6—SECTION OF TYPICAL ELECTROLYTIC LIGHTNING ARRESTER

and ground. Then in case of a ground on the line there are the same number of trays between a grounded line and the other two lines, as there are when the line is not grounded.

In the lower voltage arresters the four sections are placed in one tank, while on the higher voltages four tanks are used. The existence of the fourth section between the neutral and ground makes it necessary for the common connection or the neutral of the arrester to be insulated from the ground. In the lower voltage arresters it is now common practice to take care of this by insulating the tray structure from the tank, thus allowing the tank to be grounded, as in Fig. 12, while in the higher voltage arresters the trays are connected to the tanks and the tanks mounted on a common insulated platform as in Fig. 13.

In the earlier developments of the electrolytic lightning arrester, the electrolytes which were used were organic in their nature. A scum would form over the surface of the electrolyte and a mould would grow over the surface of the trays, and siphon out the electrolyte. This electrolyte deteriorated quite rapidly. Investigation soon developed an electrolyte which was entirely inorganic in its nature, which did not form a scum over its surface nor a mould over the surface of the trays. This inorganic electrolyte was supplied to the public as early as May, 1910, and from that date to the present time, inorganic electrolyte has been supplied by some manufacturers with all their electrolytic arresters. Several inorganic electrolytes have since been developed for use with arresters. They are alkaline in their nature, and have a comparatively long life when not used under excessive temperature.

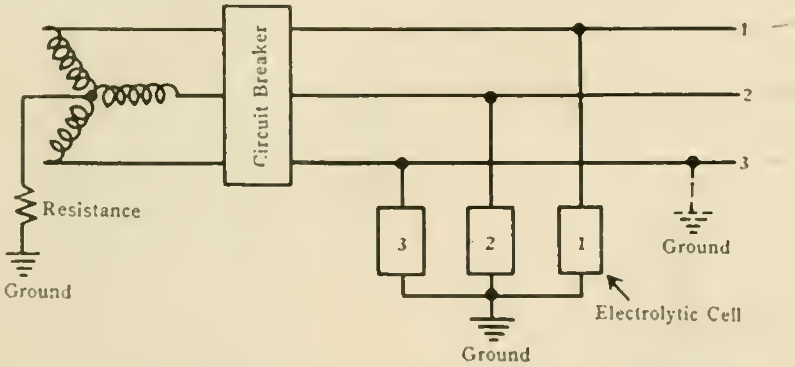


FIG. 7—SCHEME OF CONNECTIONS FOR SINGLE TANK ELECTROLYTIC LIGHTNING ARRESTER FOR A THREE-PHASE GROUNDED NEUTRAL SYSTEM

When the trays are allowed to stand for a day or two in contact with electrolyte the films will deteriorate. In order to maintain the film on the trays in good condition, it is necessary to impress voltage across them to build up the films. This is called charging; it is accomplished by bridging or short circuiting the horn gaps for a few seconds. When the horn gaps are bridged, the current flows through the phase sections marked *1*, *2*, *3*, in Fig. 11, but not through the fourth or ground section. As it is necessary to maintain the film on the ground section in good condition, this is done by inter-changing it with one of the other three sections by means of the transfer switch, shown in Fig. 14, which interchanges the connections of *2* and *4*. The charging operation is then repeated as before, the whole operation requiring less than 30 seconds, The neglect of this duty may lead to heavy momentary current following a lightning discharge, or a heavy charging current during the charging operation, as there may be only a partial film present to prevent the flow of dynamic current. The dynamic current builds up the film, but in spite of this, the flow of current may be sufficient to blow the fuses or trip the circuit breaker, as the film does not build up instantaneously, but requires a short interval of time. The regular charging of electrolytic arresters can best be insured by making it a part of the operator's daily routine. This also

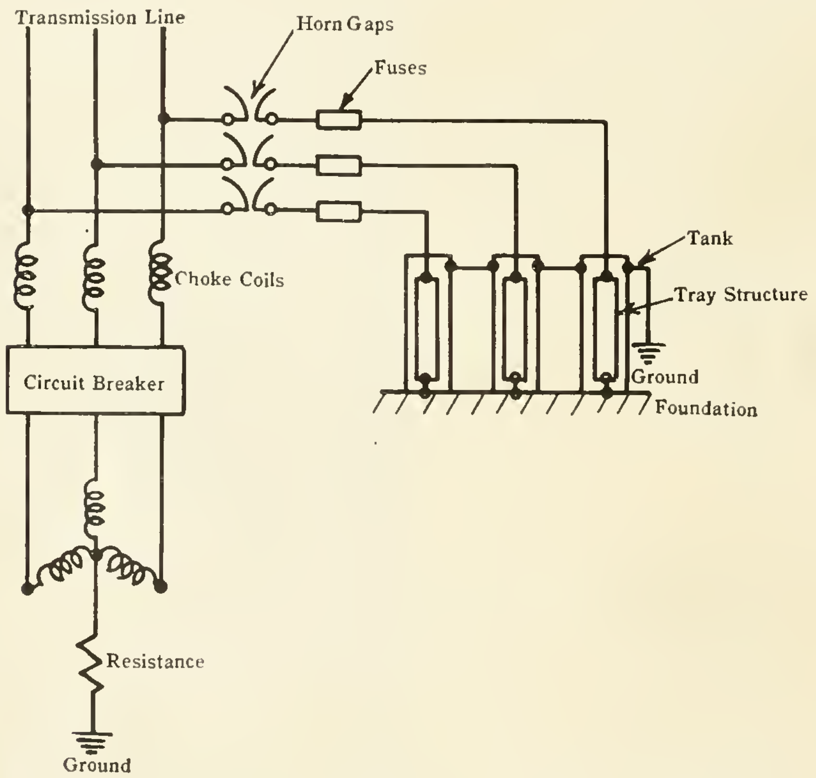


FIG. 8—SCHEME OF CONNECTIONS FOR A THREE-TANK ELECTROLYTIC ARRESTER FOR A THREE-PHASE GROUNDED NEUTRAL SYSTEM

serves to keep him familiar with and interested in the arrester. It is advisable to keep records of the operation of arresters, such as time of charging, size and color of the arc and the height to which it rises on the horns.

The location of an electrolytic lightning arrester depends to a considerable extent upon the station lay-out. All electrolytic arresters for voltages less than 10 000 volts should be mounted indoors, because for these voltages the manufacturers provide the tanks with indoor entrance bushings and because the horn gap setting at these low voltages becomes so small that the gaps would be bridged over by rain and snow. For voltages between 10 000 and 39 000 volts the arrester may be placed either indoors or outdoors as desired, or according to available space, both locations possessing their respective merits. Above 39 000 volts the manufacturers advise placing the horn gaps outdoors so that the arcs can do no damage. The tanks may be placed either indoors or outdoors. In a great many installations the horn gap structures are placed on the roof and the tanks inside the station.

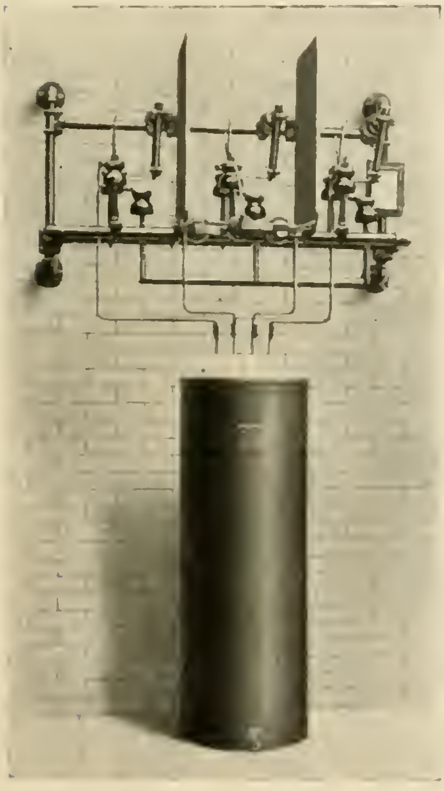


FIG. 9—ELECTROLYTIC LIGHTNING ARRESTER FOR A 7 000 VOLT THREE-PHASE GROUNDED NEUTRAL SYSTEM

Electrolytic arresters should not be installed where they are exposed to excessive temperature, as the film on the surface of the trays deteriorates more rapidly at high temperature. The disintegration of the film with heat makes charging necessary more frequently in warm than in cold weather. For several years there has been available an electrolyte which will operate successfully up to 100 degrees F., with daily charging, and at somewhat higher temperatures for shorter periods. Water cooled lightning arresters have been successfully operated under temperatures which are said to be as high as 136 degrees F. The longer the trays remain in contact with electrolyte and the higher the temperature, the greater is the rush of current when the arrester is charged. These are the reasons why transformer and generator rooms which have arresters installed near the top where the heated gasses are liable to accumulate, should be thoroughly ventilated. In very hot climates it becomes necessary to protect the tanks from the direct rays of the sun to prevent premature dissolution of the films. In such cases it is desirable to place the arrester beneath some sort of covering or on the shady side of the building, where there is free circulation of air.

Electrolytic arresters have been operated very successfully outdoors even in climates as severe as Canada, Norway and Sweden. The electrolyte freezes between 20 and 25 degrees above zero, F., but there is a considerable amount of heat stored in the jacket of oil surrounding the trays and electrolyte, and it takes a long exposure to cold weather to penetrate this jacket of oil. The electrolyte may be subjected to freezing temperatures for long periods without being injured in any way, but when frozen it becomes mushy, and its conductivity somewhat reduced, its freedom of discharge is reduced, and hence the protective power is reduced, but returns when it thaws. Fortunately, there is very little or no lightning at the time of year when the electrolyte is frozen, and its conductivity, even when frozen, is sufficient to take care of internal disturbances on a system.

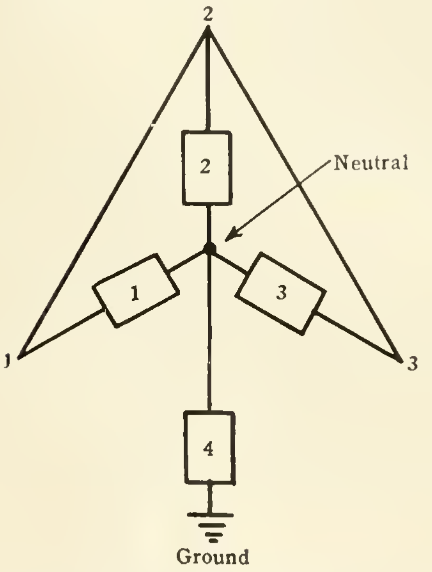


FIG. 10—VOLTAGE RELATIONS OF A THREE-PHASE UNGROUNDED NEUTRAL ELECTROLYTIC LIGHTNING ARRESTER

Cleanliness is very essential in the handling of treated aluminum trays and electrolyte, and at the installation of the arrester the tanks should be cleaned and the dirt and excelsior thoroughly removed from the trays. The tray structures should not be allowed to stand uncovered for any considerable time. The trays are filled before being placed in the tanks, but should not be filled before everything is in readiness to place the arrester in service on the line, as if the electrolyte is allowed to stand in the trays for more than two days without charging, it will dissolve the films and it will then be necessary to recharge them before the arrester is finally placed in service. The electrolyte should not be exposed so that it will collect dust, as if it is impure it will not properly form the film on the surface of the trays, and the arrester will not operate satisfactorily.

After a stack of trays have been filled with electrolyte and everything is in readiness to place them on the line, it is highly desirable that they be tested to see that all of the trays have been properly filled with electrolyte, and to give them a preliminary charge. This can be done by connecting approximately 250 volts alternating current across the cells successively (a cell consisting of two trays with electrolyte betwen them) with a bank of lamps in series. The number of lamps in the bank should be sufficient to limit the current to two amperes with the cell left out. If the film is not properly formed the lamps will burn brightly at first but will become dim as the film builds up. If the lamps do not burn brightly at first the film is properly formed; if they do not burn at all, the tray has not been filled with electrolyte. If 250 volts is not available 500 volts may be used instead, across two cells in series. If only 125 volts is available one can determine whether the trays are filled but they cannot be given a preliminary charge. If only direct current is available, this may be used, but in each case the leads must be reversed and the operation repeated for each cell, as direct current will only build up the film in one direction.

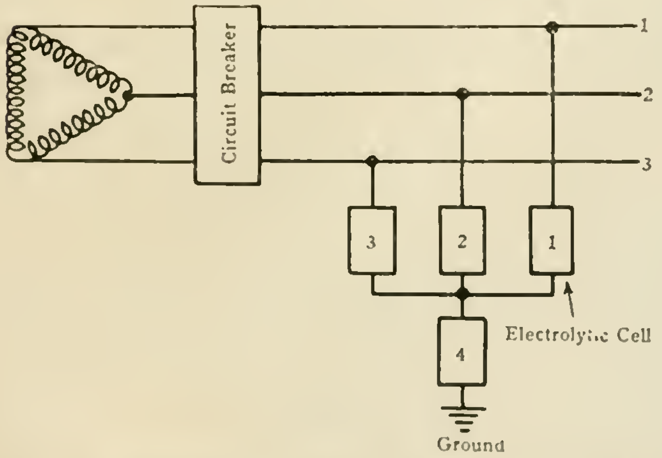


FIG. 11—SCHEME OF CONNECTIONS OF A THREE-PHASE UNGROUNDED NEUTRAL LIGHTNING ARRESTER

When a tray column filled with electrolyte is being lowered into the tank, care should be used not to spill the electrolyte, as the failure of any tray to be in contact with the adjacent one through the medium of the electrolyte will render that column inoperative. The electrolyte is not very much heavier than oil, and care should be used to avoid splashing it out when the tank is being filled with oil. Before being placed in the tank the oil should be filtered to remove iron scale and dirt held in suspension, if there be any. A good filter for this purpose may be made by spreading over the top of a funnel two or three thicknesses of fine cambric cloth from which the sizing has been removed. The oil may be poured against the side of the tank, or siphoned or pumped in, and should come within a few inches of the top of the tank or sufficiently high to cover the top of the trays and so that the bottom of the entrance bushing into the tank is immersed to the proper depth.

The various manufacturers give tables of setting for the horn gaps, which have been compiled after a thorough consideration of the settings which have given good protection in actual service under average conditions. It should be understood that a definite horn gap setting cannot be recommended as there are many factors which affect them. Unless information obtained through experience under precisely the same conditions is available, it is good practice to make the initial setting the largest given in the table, and then reduce this day by day until the gaps just arc over with switching or change of load on the system. The setting should then be slightly increased until there is no arcing at times of normal static disturbances. The minimum settings given in the various tables are the smallest that can be safely used for the respective voltages given.

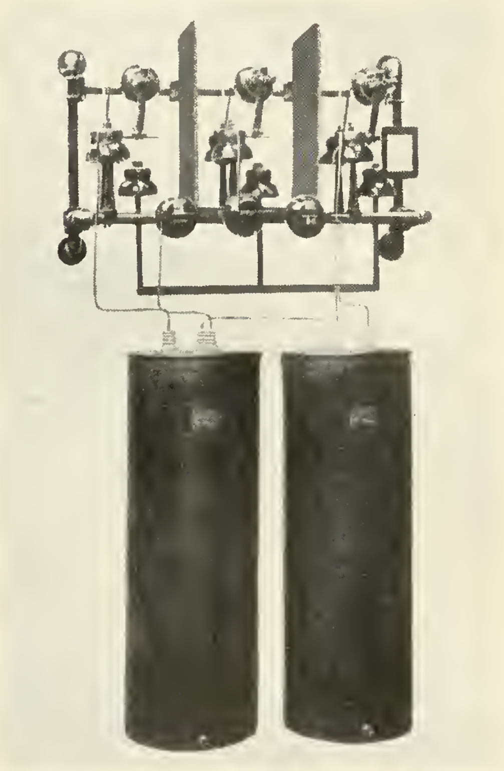


FIG. 12—ELECTROLYTIC LIGHTNING ARRESTER FOR 11 000 TO 13 500 VOLT, THREE-PHASE UNGROUNDED NEUTRAL SERVICE

The most important factors which affect the horn gap settings are the density of the surrounding atmosphere, the inherent characteristics of the circuit, the wave form of impressed voltage, and the antennae effect of grounded structures near the horns. It has been demonstarted by actual practice and by experiment that an arc will jump a greater distance in a rare atmosphere than in a dense one, so that in some cases it has been found necesary to increase the settings by one-half, at altitudes exceeding 4 000 or

5 000 feet. The tendency of a circuit to resonance, is controlled by the inductance and capacity of the circuit. This affects the horn gap settings, because when there is a tendency to resonance or surges the gaps are more readily jumped. In such cases the cause should be removed; if this is not possible, the gaps must be set farther apart. If the wave form is peaked it is necessary to use a greater horn gap setting than if the wave form more nearly approaches the sine wave, since it is the peak voltage and not the effective voltage which determines the distance which an arc will jump.

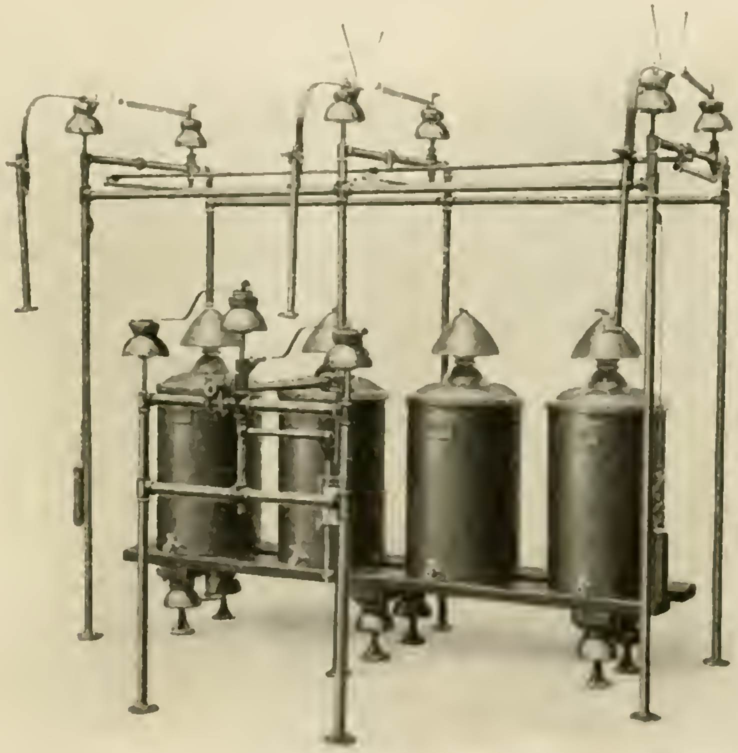


FIG. 13—ELECTROLYTIC LIGHTNING ARRESTER FOR 11 000 TO 13 000-VOLT THREE-PHASE UNGROUNDED NEUTRAL SERVICE, FOR OUTDOOR MOUNTING

The presence of grounded objects near the horn gaps affect the horn gap settings because they change the potential gradient across them. This is sometimes termed the antennae effect. It may either increase or decrease the tendency to spark over, depending upon the exact conditions.

Many operating engineers object to the presence of fuses in the circuit between the line and the electrolytic cell. In the opinion of the writer they give an added degree of protection. The principal arguments against them are space they require, and that they may blow out without the knowledge of the operator and leave that particular line without protection. This last argument is only true to a limited extent. Lightning discharges may involve thousands of amperes for a moment only. The blowing of a fuse requires the flow of current for an appreciable length of time, which depends upon the amount of current flowing. Actual service conditions have proved that an electrolytic arrester in good condition, will not blow a fuse of No. 30 copper wire except when the lightning discharge is heavy enough to destroy the arrester, if the fuses were not present. The fuses also protect the arrester in case of failure to properly maintain the film on the surface of the tray. If the arrester is not properly charged for some time, heavy current will flow when it is charged, and the fuses will blow before any harm is done to the arrester. In any case it is much less expensive to renew a fuse than it is to replace the arrester, and it leaves the line unprotected a much less length of time than if it were necessary to rebuild the arrester, or purchase and install a new one.

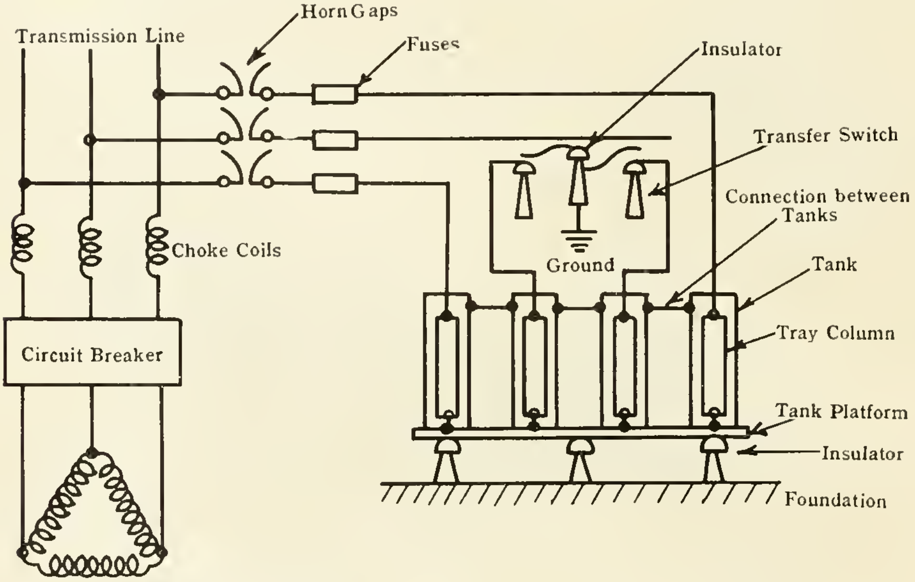


FIG. 14—TYPICAL DIAGRAM OF CONNECTIONS OF A FOUR-TANK ELECTROLYTIC LIGHTNING ARRESTER FOR A THREE-PHASE UNGROUNDED NEUTRAL SYSTEM

When an arrester is being initially placed in service, after making sure that all is in working order it is advisable to bridge the horn gaps two or three times to completely form the film. If before being placed in service the arrester has remained unconnected for more than two or three days, or if, having once been in service, twice the normal charging period has elapsed without its being charged, it is not best to impress the full potential across the trays at once, but the film should be reformed by one of the following methods. An arc should be started between the horn gaps with about one-half of the line voltage impressed across them, and the gaps at once opened. This operation should be repeated ten or fifteen times, just as in normal charging of the arrester as described before. Each time the gaps are bridged, the film on the trays will be built up higher than it was before, until it has been built up to the highest point to which the voltage is capable of building it. The voltage should then be raised to about three-fourths full line voltage, and the momentary charges repeated as before. The full line voltage may then be impressed across the horn and the momentary arcs repeated. The proper condition of the film will be indicated by a bluish, crackling, static spark on the horn.

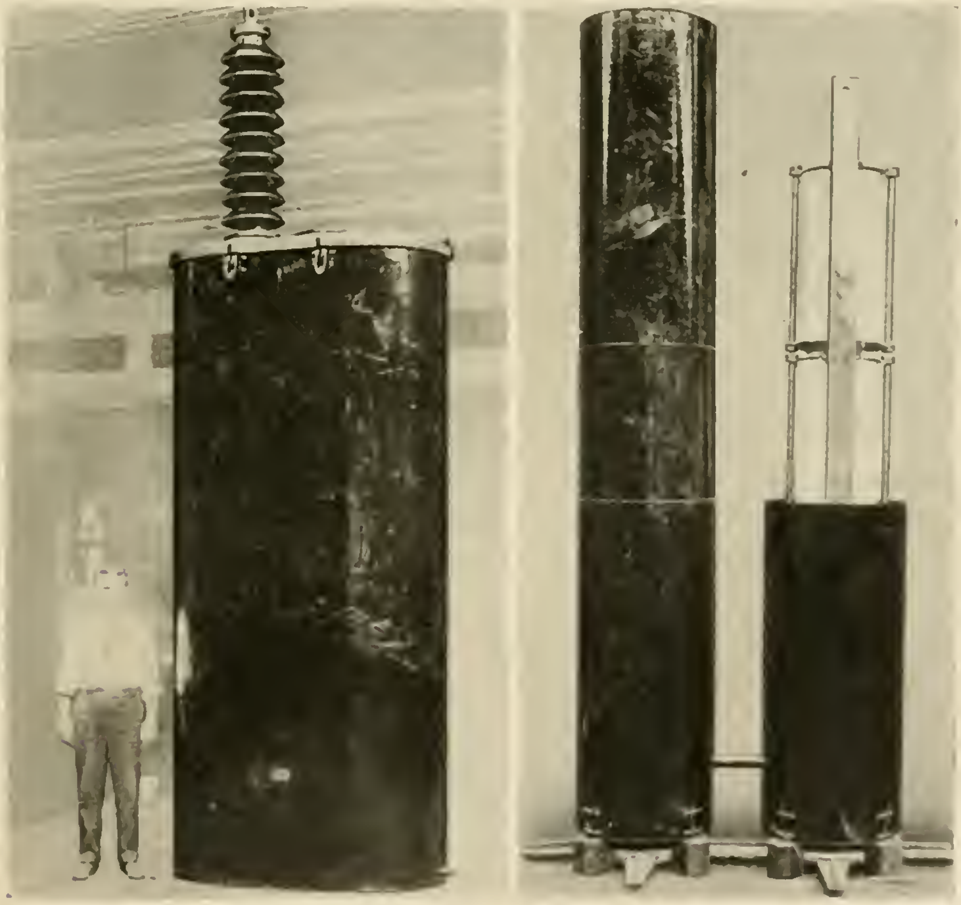


FIG. 15—VIEWS OF AN ELECTROLYTIC LIGHTNING ARRESTER FOR A 165 000 VOLT GROUNDED NEUTRAL SYSTEM

The view at the left shows the complete arrester in its tank, while that at the right shows the tray structure and the arrangement of the micarta tubes. These arresters are for use on the lines of the Pacific Light and Power Corporation.

In a great many cases the reduced voltages can not be obtained. In this case, place in series between the horn gaps and the tanks instead of the ordinary fuse, a fuse of No. 30 copper wire, or one of the strands from an ordinary lamp cord, and bridge the horn gaps, as before. The fuse will blow, and the film will be built up higher than it was before. This operation should be repeated fifteen or twenty times or until such time that a bluish static spark is obtained on the horns. With persistent effort, it is very seldom that the film can not be properly built up by this method.

It often happens that in the process of building up the films as given in the above paragraph the electrolyte and oil may become quite warm. This is especially true where the film has been allowed to become quite low, and there has been some difficulty in building up the film. The electrolyte and oil may also become quite warm after long severe lightning discharges. As mentioned before, the film dissolves more rapidly when in contact with warm electrolyte than at lower temperatures, and in such cases it may be advisable to occasionally bridge the horn gaps afterwards until the arrester has reached normal operating temperatures, or a temperature less than 100 degrees F.

By bridging the horn gaps several times in succession as explained before, a reliable indication of the condition of the arrester may be obtained. If a heavy, reddish, fluffy arc is obtained, which runs high on the horns, the arrester is in bad condition and the film on the surface of the trays is not perfectly formed. If the trays are not in contact with each other through the medium of the electrolyte, or if the space between them is filled with oil, there will be very little, if any, arc on the horns. The arrester is in good condition if there is obtained a bluish, crackling static spark which does not rise high on the horns. The height to which the normal static spark rises depends upon the electrostatic capacity of the arrester, which in turn depends upon the active area of the tray in contact with electrolyte. A static arc rising high on the horns does not indicate that the arrester is consuming any considerable amount of power, because most of the current flowing is capacity current. Instead it indicates the effective condition of the arrester.

A rumbling sound in the tanks during the charging operation is caused by an arc jumping between the trays. This is usually caused by a tray not being sufficiently full of electrolyte. If a rumbling sound is heard, the trays should at once be removed and examined.

If no dynamic arc occurs on the horns and only a feeble spark appears, it indicates an open circuit in the arrester, which may have been caused by some tray being left unfilled, the voltage between trays not being sufficient to break down the oil. In this case the individual trays should be tested by the preliminary test refered to previously.

There is normally not very much deterioration of trays in arresters which have been in ordinary service under average conditions. The trays should, unless punctured, or mechanically injured, last for several years. The wear upon a tray depends upon the number and severity of the discharges which it is called upon to take care of, and the frequency of the charging operation. There is a slight tendency for the trays to lose their electrolyte, especially those which are near the top. During long heavy discharges or when there is a heavy rush of current due to insufficient charging, the oil becomes heated and rises to the top, absorbing more of the electrolyte. Heavy discharges or rush currents may form large bubbles on the surface of those trays which are warm or have least electrolyte. When the arresters are in good condition, the bubbles which form during a discharge are small and readily escape over the surface, but when some time has elapsed since charging, and the film has somewhat deteriorated, these bubbles may be formed rapidly enough to push some of the electrolyte out of the trays. Though it is impossible to observe the phenomena, it is thought that the larger bubbles cause arcs to form between the trays, which continue either until they have been extinguished or until the tray has been punctured and drained of electrolyte. In arresters which are new or in good condition, there is very little liability of puncture of the trays, but as the electrolyte becomes older and its distribution unequal, the danger of puncture increases.

Electrolytic arresters should be inspected at frequent intervals to see if they are in good condition, especially after a year's service. They should be carefully examined each year just before the lightning season. If at any time they are found not to be in good condition, they should be overhauled, the trays should be cleaned, by washing with gasoline or good soap, rinsed in clear water, damaged trays replaced, and all the trays filled with new electrolyte. It is not necessary to renew the oil, but such electrolyte as may have accumulated should be removed from the bottom of the tanks and the oil maintained at its proper height.

SOME FEATURES OF THE PACIFIC LIGHT AND POWER SYSTEM

B. P. ROWE

THE Pacific Light and Power Corporation is now constructing a transmission system with generating stations and substations which will operate at a line voltage of 150 000 volts. This is the highest voltage which has yet been utilized for commercial transmission. The power will be generated at two hydroelectric generating stations, located on Big Creek, about 70 miles from Fresno, California. These stations are practically duplicates and are situated about four miles apart. Each station is designed for an ultimate capacity of 105 000 k. v. a., generated at 6 600 volts, three phase, 50 cycles, and will contain six 17 500 k. v. a. water wheel driven revolving field alternators, two being installed with the initial equipment, together with two 250 volt exciters. Those for power house No. 1 are rated at 150 kilowatts, and for power house No. 2 at 200 kilowatts. One exciter in each station will be motor driven and one water wheel driven.

The current, generated at 6 600 volts, will be stepped up to 150 000 volts through banks of 5 833 k. v. a. transformers connected in sets of three, with the low tension windings delta and the high tension star connected. Each station will have an initial installation of two banks of these transformers and ultimately six banks.

Power will be transmitted from these stations by duplicate sets of three-phase transmission lines a distance of 275 miles to the Big Creek sub-station at Los Angeles, the generating stations being connected so that they may be operated singly or in parallel on either one or both transmission lines. Each line is designed to transmit approximately 60 000 k. v. a.

At Borel Junction, about 135 miles from Los Angeles, a switching station will be established, and additional power, approximately 13 500 k. v. a. at 60 000 volts, will be supplied from the Kern River system through step-up transformers. Most of this power will be generated from five 2 000 kilowatt, two-phase water wheel driven generators located at Borel, and the balance from the Kern River system.

At the Big Creek sub-station, there will be banks of step-down transformers which will reduce the voltage from 150 000 to 6 600 or 15 000 volts, as required. At this station two 15 000 k. v. a. synchronous condensers will be connected to the system through a set of 6 600 volt bus-bars. These machines can be operated either as motors or generators, and may be used initially to assist in maintaining a better power-factor on the system. Later, the machines may be used as generators in one of the power houses.

Additional power will also be supplied to the Los Angeles system over 60 000 volt lines from the Kern River system. Power amounting to approximately 15 000 k. v. a. will also be supplied by local generating stations through step-up transformers.

The principal load at Los Angeles will be the power supplied to the Pacific Electric and the Los Angeles Railway systems. The railways operate from 15 000 volt transmission lines, and the power is nearly all converted into direct current through motor-generator sets of large size.

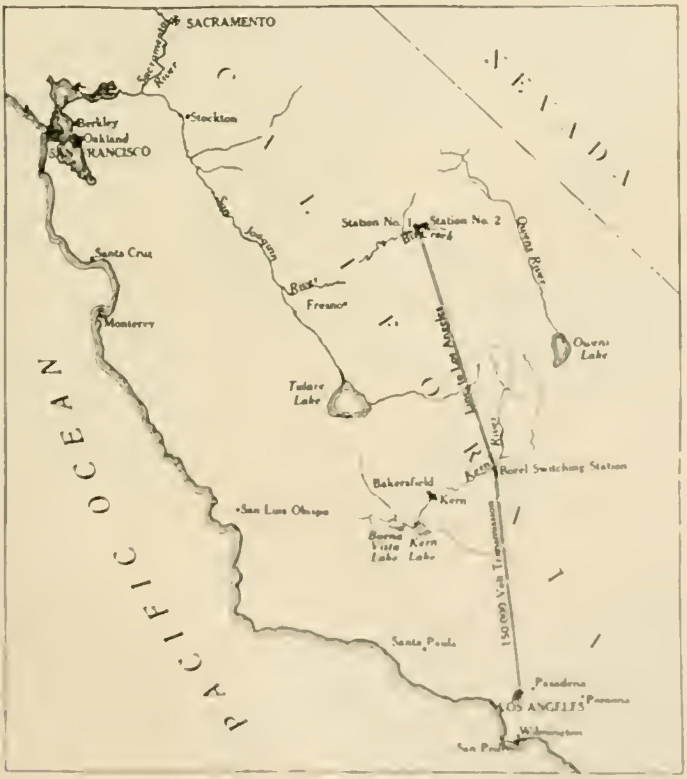


FIG. 1—OUTLINE SKETCH SHOWING LOCATION OF TRANSMISSION LINES

A general idea of the transmission system may be obtained from Fig. 1. The transmission lines from power houses Nos. 1 and 2 may be operated either with or without the neutral grounded and, although it is expected that the neutral points of the transformer banks at the power houses will be grounded, provision is made to operate ungrounded if desired, and all high tension apparatus is insulated with this possibility in view.

The step-up transformers at Borel Junction will be connected with the neutral of the low tension side grounded, thus grounding the 60 000 volt system. The step-down transformers at Kern substation will also have the neutral of the 60 000 volt system grounded, and the 15 000 volt generating system will be grounded. No reactance or resistance is inserted in these grounds. Whenever the turbines and engine driven generators on the Kern River system are operated in parallel, the ground is disconnected from the neutral of the engine driven machines. The neutral is not grounded at any of the other sub-stations, and the 15 000 volt distribution system in Los Angeles is operated without the neutral grounded. It is expected that the power-factor of the load will be approximately 85 percent for initial conditions, when operated without synchronous condensers.

The Pacific Light and Power Corporation, through their engineers, the Stone and Webster Engineering Corporation of Boston, contracted for all the apparatus for the initial installation and

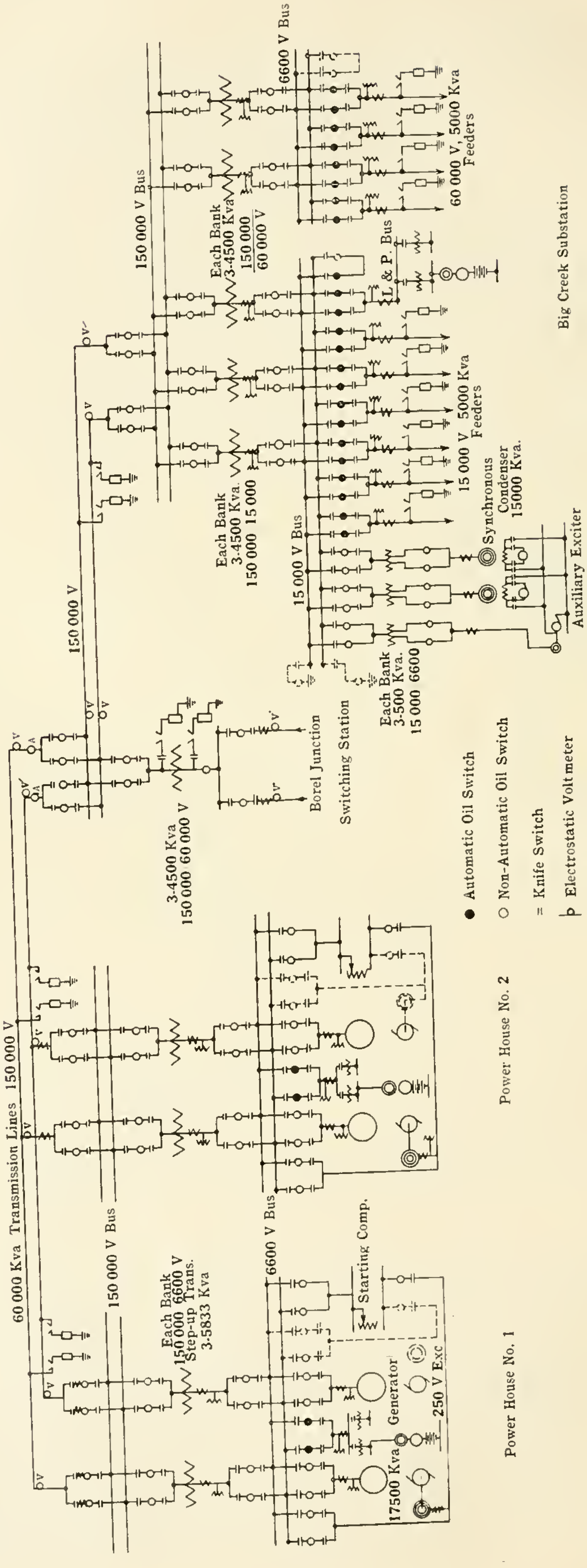

6600 V Bus
60 000 V, 5000 Kva Feeders
150 000 V Bus
Each Bank 3-4500 Kva 150 000 / 60 000 V
L & P. Bus
Big Creek Substation
150 000 V
Each Bank 3-4500 Kva. 150 000 15 000
15 000 V Bus
15 000 V 5000 Kva Feeders
Synchronous Condenser 15000 Kva.
Auxiliary Exciter
Each Bank 3-500 Kva. 15 000 6600
Switching Station
Borel Junction
3-4500 Kva 150 000 60 000 V
Automatic Oil Switch
Non-Automatic Oil Switch
Knife Switch
Electrostatic Voltmeter
60 000 Kva Transmission Lines 150 000 V
150 000 V Bus
Each Bank 150 000 6600 V Step-up Trans. 3-5833 Kva
6600 V Bus
Starting Comp.
17500 Kva Generator
250 V Exc
Power House No. 2
Power House No. 1

FIG. 2—SINGLE LINE DIAGRAM OF CONNECTIONS OF DIFFERENT STATIONS

much of the material is now on the ground. The high tension apparatus involves disconnecting switches, oil switches and lightning arresters for 150 000 volt service, together with the transformers to raise or lower the voltage from 150 000 volts to the working voltage. All 150 000 volt, high tension apparatus is tested at the factory at 375 000 volts for one minute and at 300 000 volts after installation for one minute.

The general scheme of connection for lines, switching apparatus, etc., for the new installation is shown in the single line diagram, Fig. 2. All of the switching devices from generators to lines, as well as the high tension switching devices in the sub-stations, will be non-automatic. Provision is made, however, for operating the oil switches automatically at a later date, if desired. By means of the switching devices provided, it will be possible to operate power houses No. 1 and No. 2 in parallel with the multiple connection made at only one point, this being the bus junction switch between the two 15 000 volt busses in the Big Creek sub-station. Again, power houses Nos. 1 and 2 may be operated separately if desired, each with its own transmission line and 15 000 volt bus in the Big Creek sub-station Or both may be operated in parallel on the 150 000 volt lines, this method being used to equalize the load between the transmission lines, and will be employed when one line is out of commission. The sub-station at Borel Junction may be connected in to supply power to either or both transmission lines in parallel with the generating stations, or this source of power may be cut off altogether.

If desired, the system may be operated at 135 000 volts, as the apparatus and meters are proportioned to provide for the extra current which would flow at the lower voltage with the rated output in k. v. a. Voltage regulation will be maintained by Tirrill regulators, a large regulator being installed in each of the two generating stations. Another similar regulator will be installed and operated in connection with the synchronous condenser in the Big Creek sub-station. The 150 000 volt oil switching devices are guaranteed to rupture short-circuits on the system when connected to five generating units in each station of a total capacity of 87 500 k. v. a., the reactance of the generators being approximately eight percent. The large oil switches connected to the 6 600 volt bus-bars for use with generators and step-up transformers will each have a rupturing capacity of at least 75 000 k. v. a. There will be one pair of automatic circuit breakers in each power station, these being used to carry power for station auxiliaries.

All of the oil switches are either motor or solenoid operated, those in power house No. 2 being entirely solenoid operated. A complete set of disconnecting switches and double set of bus-bars for selective switching is indicated in Fig. 2. The disconnecting switches will be mounted on the station walls with blades vertical when closed, and will be operated by switch hook poles. All of the 150 000 volt bus-bars and connections will be made of 1.25 inch iron pipe supported from porcelain insulators.

The electrically operated switching devices and accessories in power houses Nos. 1 and 2 will be operated from bench boards, the inclined top being utilized for the control switches, indicators and miniature bus system in the usual manner, while the upright rear portion will contain panels on which will be mounted the meters and indicating instruments. One section in each bench board will contain the Tirrill regulator. The station voltmeters and synchroscopes will be mounted on swinging panels at the ends. The front of the lower portion of each bench board will be utilized for the exciter rheostat hand wheels and sprocket control as well as relays and testing receptacles for the meter circuits. Each bench board will contain 15 sections, consisting of two exciter sections, two generator sections with two blank sections for future generators, one regulator section, one blank future regulator section, one station auxiliary section, two step-up transformer sections, with two blank sections for future transformers, and two

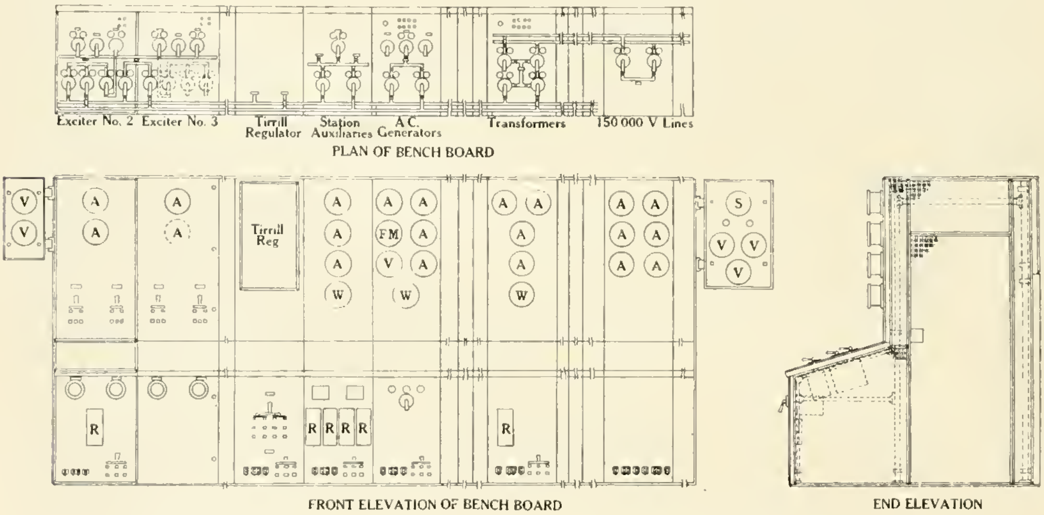


FIG. 3—SWITCHBOARD ARRANGEMENT AT POWER HOUSES NOS. 1 AND 2

outgoing feeder sections each to control one 150 000 volt, three-phase, outgoing feeder.

The feeder control panels will be standard 90 inch straight switchboard panels, each to contain the solenoid-operated alternating-current generator switches and the exciter main and equalizer solenoid-operated switches, all of these being operated from the bench board. These panels form a separate independent switchboard. The alternating-current generator rheostats are motor operated and controlled from the bench board. The station low tension lighting and power system as well as the storage batteries and charging system are likewise operated from a panel switchboard.

All of the switchboards as well as the panels in the bench board are of black Monson slate. The apparatus mounted on the panels, except miniature bus-bars and current carrying parts, are finished in black marine finish. Fig. 3 shows a general view of the bench board. The rear is enclosed with iron grill work, entrance to the interior being obtained by doors in the grill at each end. Watthour meters are mounted on panels in the rear.

The switching equipment in the Borel Junction sub-station is similar to that in power station No. 2 except that all oil switches are hand operated. The switching apparatus in the Big Creek sub-station is similar in character to that in power house No. 1, and is an extension of an existing system already in operation.

ONE HUNDRED AND FIFTY THOUSAND VOLT POWER TRANSFORMERS

WITH ESPECIAL REFERENCE TO THE INSTALLATION OF THE PACIFIC LIGHT & POWER CORPORATION

W. M DANN

THE transformers to be used in the transmission of power over the system of the Pacific Light & Power Corporation represent the latest step in the evolution from what was at one time considered "high voltage" to a working pressure of 150 000 volts. The art of designing, building and insulating has progressed to the point where the manufacturer can offer transformers for this latter voltage with confidence that they will be as reliable as the transformers now in service in large numbers for little more than half that voltage. While the transformers being installed by the Corporation are distinguished chiefly by the high voltage at which they will operate, they are also conspicuous examples of the "Class A-1" rating recently advocated before the American Institute of Electrical Engineers, i. e., they are designed for continuous service at their rated load without exceeding a temperature rise of 50 degrees C. in any part. They have no overload rating in addition to this single rating.

In their Big Creek generating station, 17 500 k.v.a. generators will produce three-phase, 50 cycle energy at 6 600 volts. This will be stepped up to the transmitting voltage, 150 000 volts, by means of banks of three 5 833 k.v.a. transformers, one of which is shown in Fig. 1. The low voltage windings are to be connected in delta. The high voltage windings will be connected in star with the neutral point of the star grounded. While this limits the stress to ground to 86 700 volts, the system may at some time be operated without the ground connection. This has been generously anticipated by a requirement on the part of the Corporation that the insulation shall withstand a one minute test between the windings and the core of two and one-half times the normal working voltage between line wires, i. e., 375 000 volts for the high voltage winding and 16 500 volts for the low voltage winding. These transformers are thus the highest voltage power transformers ever built. As far as the insulation is concerned, they would be suitable for continuous operation at 187 500 volts, with a slight increase in the size of the terminals. At this working voltage they would have the usually accepted margin of safety represented by the double voltage test recommended by the A. I. E. E. Standardization Rules. It is a striking illustration of their size to say that if they were re-designed and converted into 22 000 volt transformers having the same physical dimensions, they would become thoroughly practicable 50 cycle, single-phase, 50 degree rise transformers of not less than 30 000 k.v.a. capacity. In other words, reducing the test voltage from 375 000 volts to the normal test required for a 22 000 volt transformer would multiply the output per unit of space occupied between five and six times.

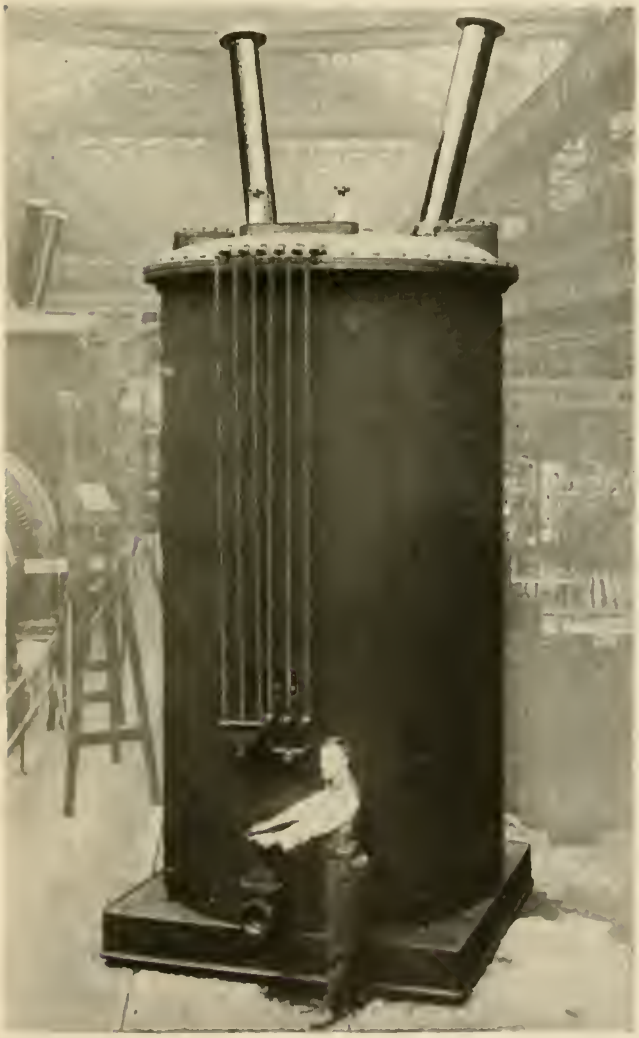


FIG. 1—5 833 K.V.A. TRANSFORMER FOR STEPPING UP VOLTAGE FROM 6 000 TO 150 000 VOLTS

The insulation between turns is a matter of particular importance in any high voltage transformer. This is especially true of the turns next to the line, as the insulation at such points must bear the brunt of any line disturbances that reach the transformer. With the surges that are likely to occur due to lightning and other potential disturbances on a line nearly 300 miles long operating at 150 000 volts, the matter of "end turn" insulation becomes extremely important. Fig. 2 shows one of the line side high voltage coils of the 5 833 k.v.a. transformer ready to receive the vacuum drying and varnish treatment Inspection will show the very heavy padding of insulation between the turns which show white in the cut. A few years ago the insulation between turns throughout the interior of the windings of these transformers would have been considered adequate for use between the end turns of transformers wound for 100 000 volts. The high voltage terminals are of the condenser type, in its most modern form, as shown in Fig. 3.

The mechanical forces tending to separate the primary and secondary coils of a large transformer under external short-circuit conditions are hard to appreciate unless one has seen the destructive effects of such conditions on a transformer not properly braced. These forces act in two ways; there is a tendency for the primary and secondary coils to separate from each other along the axis perpendicular to the plane of the coils. This very tendency is utilized in the familiar "constant current" regulating transformer used for lighting purposes. Here the repulsion due to the normal current is balanced by counterweights and any departures from the normal current due to changes in the load conditions move the coils to a new position where the normal current and repulsion are again established.

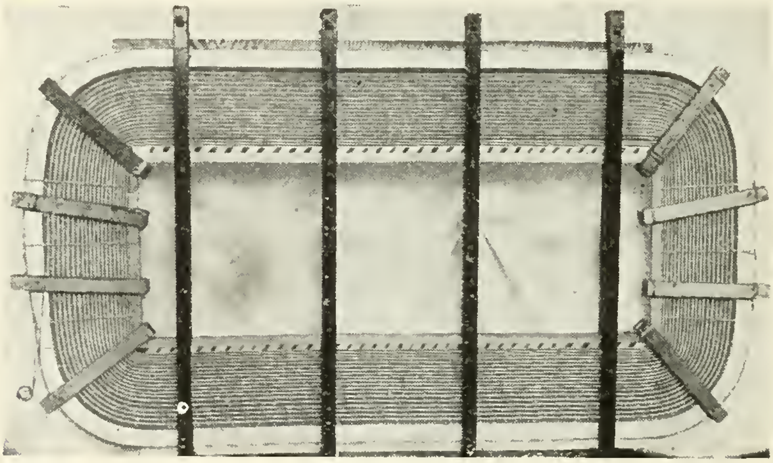


FIG. 2—LINE SIDE HIGH TENSION COIL USED IN TRANSFORMER SHOWN IN FIG. 1
Showing the extra heavy insulation between turns.

The ends of the outside coils of the power transformer are the only portions of the winding which are not securely confined by the core. The violent tendency for the coils to get away from each other under short-circuit conditions is therefore fully neutralized if on the ends of the groups the coils are braced adequately enough to make such a thing impossible. Fig. 4, which shows the 5 833 k.v.a. transformer out of its tank, illustrates the bracing of the coils. Heavy wood plates reinforced by boiler plate press against the sides of both of the end coils where they project beyond the core. When the set screws are tightened up and the lock nuts set, the whole group of coils is solidly clamped together. The mechanical stresses are then transmitted to the cast end frames which are proportioned to withstand the maximum stresses that can be developed. The second tendency exhibits itself in the plane of the coil and not at right angles to it. If each conductor of the primary coil lay directly opposite a conductor in the adjacent secondary coil, there would be no force of repulsion except in the direction perpendicular to the plane of the coil as already described and as illustrated in Fig. 5. The sizes of the conductors and the number of turns in the primary and secondary coils are usually different however, and the conditions shown in Fig. 5 would rarely exist. As a consequence there is almost always a component of the repulsion acting in a direction lying within the plane of the coils as seen in Fig. 6. As before, this force can operate only at the ends of the coils. At other points the core securely holds the conductors in place. In properly designed transformers of large capacity this is minimized, though rarely eliminated, by making the width of the primary and secondary coils the same or as nearly the same as possible.

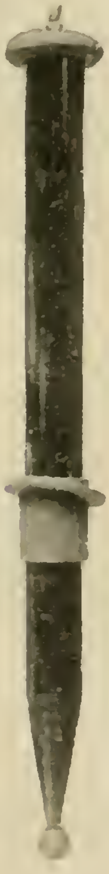


FIG. 3—CONDENSER TERMINAL*

Additional bracing for this component of the repulsion, as used in these large transformers, will be seen in Fig. 4 and in sketch form in Fig. 6. Strong braces of "T" section pass through the opening of the coils at the top and bottom and heavy bolts at the ends of the T-bars serve to keep the coils in place under conditions of mechanical stress.

This rugged and substantial mechanical construction is in keeping with the modern requirements for power transformers. The generator capacity of each of the two Big Creek power houses will ultimately be 105 000 k.v.a. A system of this size is large enough to maintain sufficient voltage under short-circuit conditions to make the mechanical stress disastrous if not fully taken into account in the transformer design.

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*This terminal has a creepage surface of 60 inches from flange to static shield. Diameter of central conductor, 2.5 inches. External diameter of condenser, 0.875 inches. Diameter of static shield, 15 inches. Radius of roll at edge, 1.5 inches. This terminal will not flash over at 400 000 volts. It will be satisfactory on a service voltage of 165 000 volts at 60 cycles, and 220 000 volts at 25 cycles, the difference being caused by the difference in dielectric losses.

At the Borel Junction switching station, 13 500 k.v.a. at 60 000 volts will be added to the 150 000 volt system. This power will come in through a bank of three 4 500 k.v.a. tie-in transformers having a normal ratio of 60 000 to 150 000 volts. This same design of transformer will be used in the Big Creek sub-station at Los Angeles to step down to 15 000 or 60 000 volt feeders. The low voltage winding can be connected for full capacity at either 72 000, 60 000, 18 000 or 15 000 volts. While their capacity is less than that of the transformers in the generating stations, their dimensions are greater for three reasons:—(a) They are to be connected in delta on the 150 000 volt line. This means that they will require more insulation because they will have 150 000 volts impressed across the total high voltage winding while the 5 833 k.v.a. units will have 86 700 volts impressed across the total high voltage winding. (b) They have a low voltage winding for 72 000 volts. This requires more room for insulation. (c) They

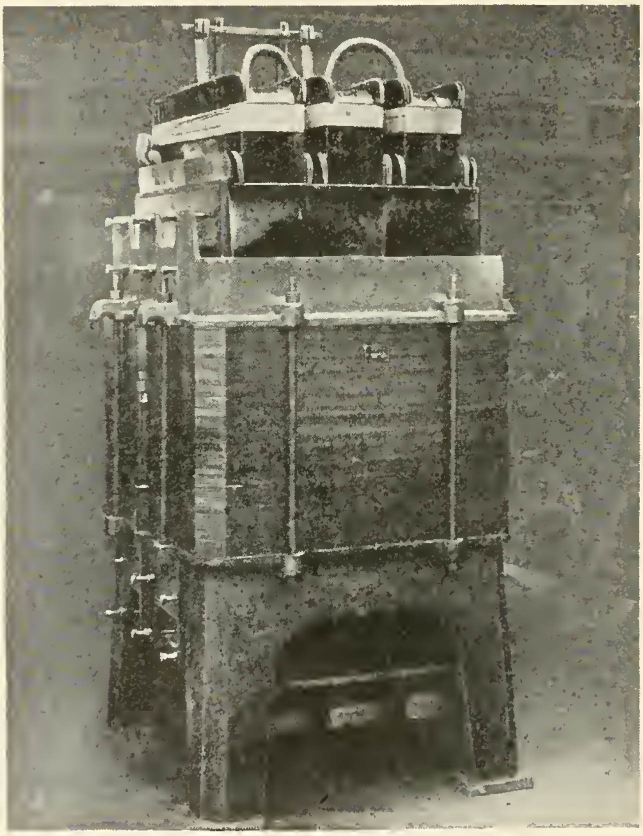
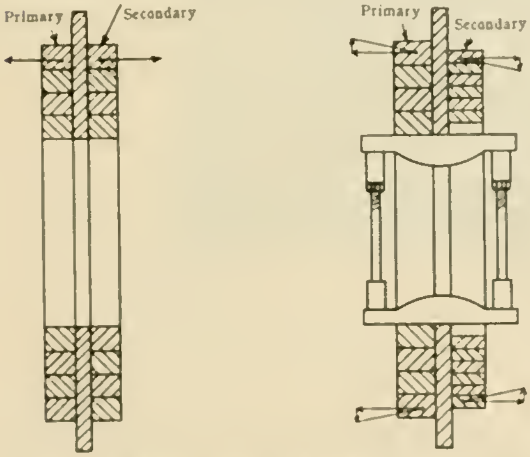


FIG. 4—5833 K.V.A. TRANSFORMERS SHOWN IN FIG. 1 OUT OF CASE

have a low voltage winding split up into four parts, to be connected in series or in parallel and this requires more room than a straight series connection.

The appearance of the 4 500 k.v.a. transformer is much the same as the 5 833 k.v.a. unit with the exception that both the low voltage and the high voltage terminals are of the condenser type. If it were re-designed and converted into a *22* 000 volt transformer, with physical dimensions unchanged, it could be made into a 50 cycle, single-phase, 50 degree rise transformer of not less than 40 000 k.v.a., or something over eight times the capacity at the high voltage. A glimpse of one of these transformers can be seen at the left of the 5 833 k.v.a. unit in Fig. 1.

Fig. 7 shows a top view of the windings for the 4 500 k.v.a. transformer before the core is built up. A striking feature is the absence of terminal boards and bars. The terminals are mounted on substantial "bridges" made up of insulating material and attached securely to the sheets of insulating material between the groups of coils. The link connections necessary for connecting in series or multiple are made on these bridges. One of the channels which covers up these link connections is shown in place while the other is removed and is seen at the right of the picture. All fullerboard and micarta insulation is made from drawings. The various parts, therefore, can be assembled in the complete transformer with accuracy and any part can easily be duplicated with assurance that it will fit in its place.



FIGS. 5 AND 6—DIAGRAMS SHOWING FORCES OF REPULSION BETWEEN TRANSFORMER COILS

The tanks enclosing these transformers are cylindrical, which form is well known to be the strongest and most substantial construction that can be used. They are made of boiler iron with welded seams. Welding processes have been so perfected that the seams are as strong if not stronger than the body of the material itself. For mechanical strength the bottom of the tank is "dished" like the cover. The base casting has a recess which fits the cur vature of the bottom of the tank. When the metal gasket is in place between the cover and the tank and the cover is drawn down tight with the numerous bolts provided, the case becomes practically air tight. There is always a tendency for a transformer case to "breathe" as its temperature changes, due to changes in load conditions, but an air tight case of course effectively prevents the passage in and out of air with the moisture that is always present in greater or less degre. A blow-off or vent is provided on the cover, piped to a sewer, and a diaphragm of thin sheet metal is placed between it and the pipe connection. Any excessive internal pressure will be relieved by the rupture of this diaphragm, and any oil that might follow a violent increase of pressure is simply conveyed to the sewer.

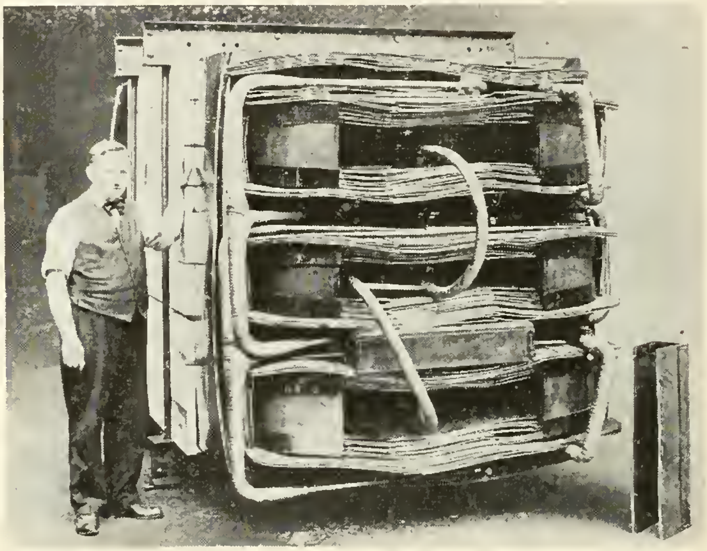


FIG. 7—TOP VIEW OF COILS FOR 4 500 K.V.A. 150 000 VOLT TRANSFORMER BEFORE ASSEMBLING WITH CORE

SWITCHBOARDS FOR ALTERNATING-CURRENT POWER STATIONS—VI

THE ELECTRICALLY OPERATED SWITCHBOARD

C. H. SANDERSON

THE ELECTRICALLY OPERATED SWITCHBOARD usually takes one of three general forms; namely, the panel board (Figs. 2 and 3), the combination control desk and elevated instrument board, (Figs. 4, 5 and 7), or the combination pedestal and instrument post board (Fig. 8).

As in the application of self-contained or remote mechanically controlled switchboards, there is no well defined field to which any of the three forms is confined. More than in any other type of switchboard does the electrically operated board approach the ideal of the designing engineer, as it is almost entirely uninfluenced by the form of the apparatus which it controls. This fact, moreover, accounts largely for the great variety of combinations, some of which are shown in Fig. 1.

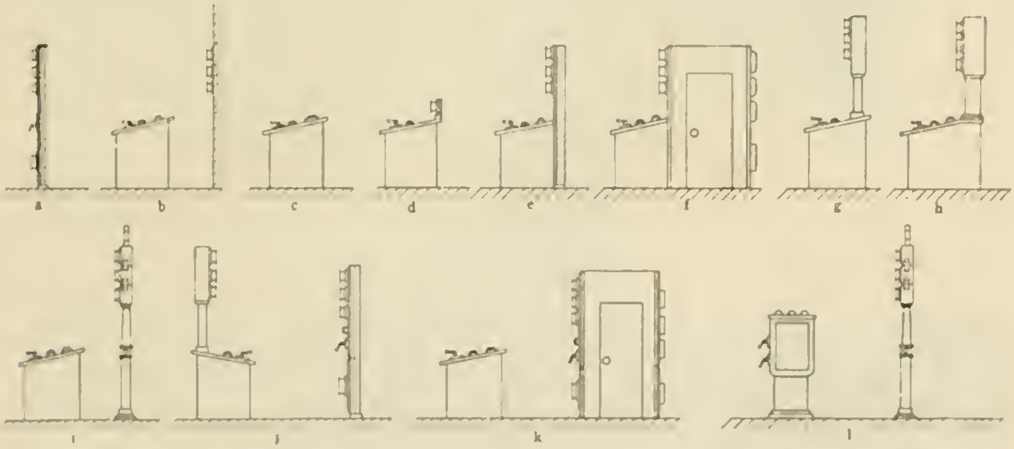


FIG. 1—VARIOUS FORMS OF CONTROL SWITCHBOARDS FOR ELECTRICALLY-OPERATED EQUIPMENT

There are, however, certain general conditions which influence a choice of design and which must be recognized before a satisfactory arrangement can be obtained. The most important of these are:—

1—The capacity of the station.
2—The number of generator, feeder, bus-tie and exciter circuits to be controlled.
3—The relative proportion of feeders to generator circuits.
4—The scheme of bus-bars and inter-connections.
5—The location and arrangements of the switchboard gallery as regards the location and arrangement of the station apparatus.
6—The first cost and maintenance cost.
7—The system of operation; or, the usual manner in which the various circuits will be operated, considered together with the provisional arrangements for emergency use, or alternate scheme of operation
8—The number and kind of instruments and control devices to be used.

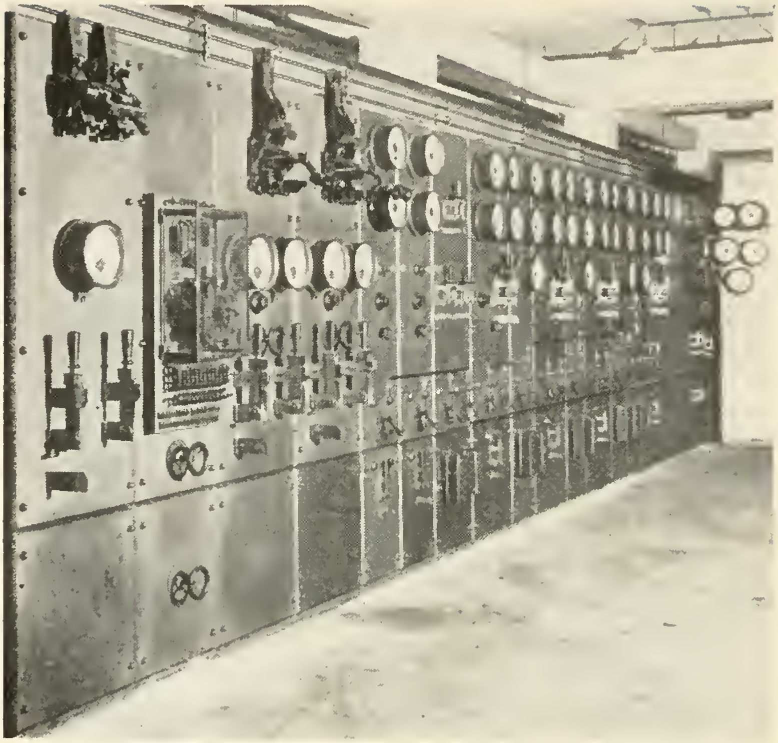


FIG. 2—PANEL TYPE ELECTRICALLY-OPERATED SWITCHBOARD

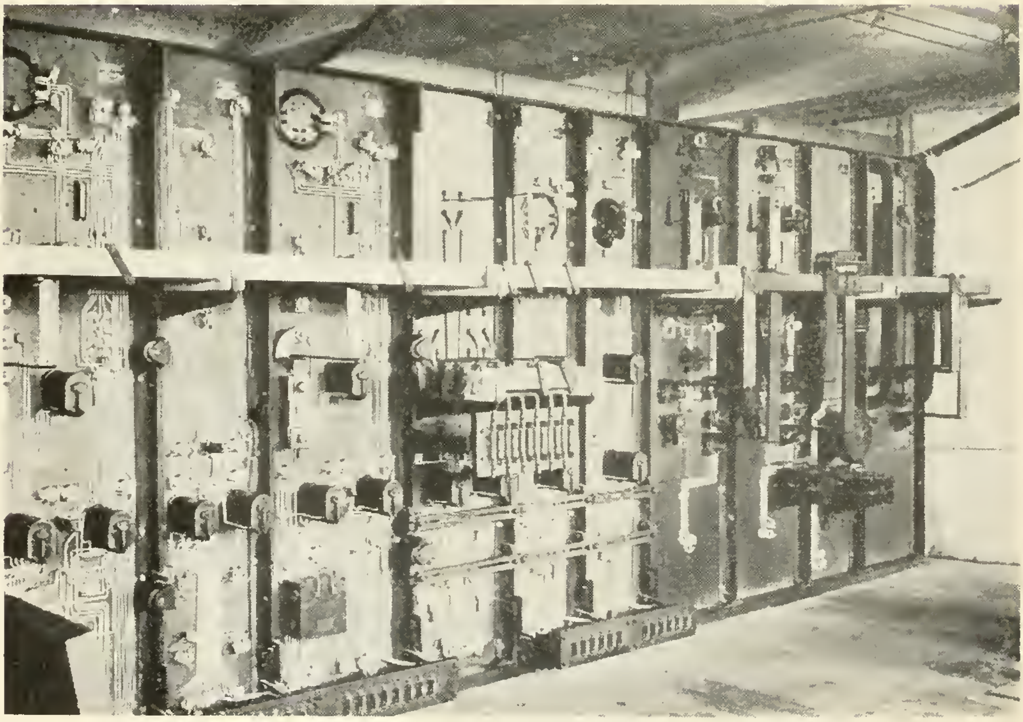


FIG 3—REAR VIEW OF SWITCHBOARD SHOWN IN FIG. I

A discussion of the various forms of control shown in Figs. 1 to 8 will illustrate the usual methods in which the relation of the above conditions to the type of board are recognized.

THE PANEL BOARD

The panel board is the least expensive and the simplest in construction. It is frequently chosen for plants of moderate capacity, and, occasionally for those of high capacity where the number of circuits are few and the length of the board is therefore kept within a space which may be covered almost instantly by the operator. The panel board is invariably chosen for sub-stations, as it must generally harmonize with, and probably be an addition to the panel board controlling the low tension alternating and the direct current circuits Often the control for the hand-operated and the electrically-operated apparatus of the sub-station are combined on the same panel, thus obtaining a small, inexpensive and simple board.

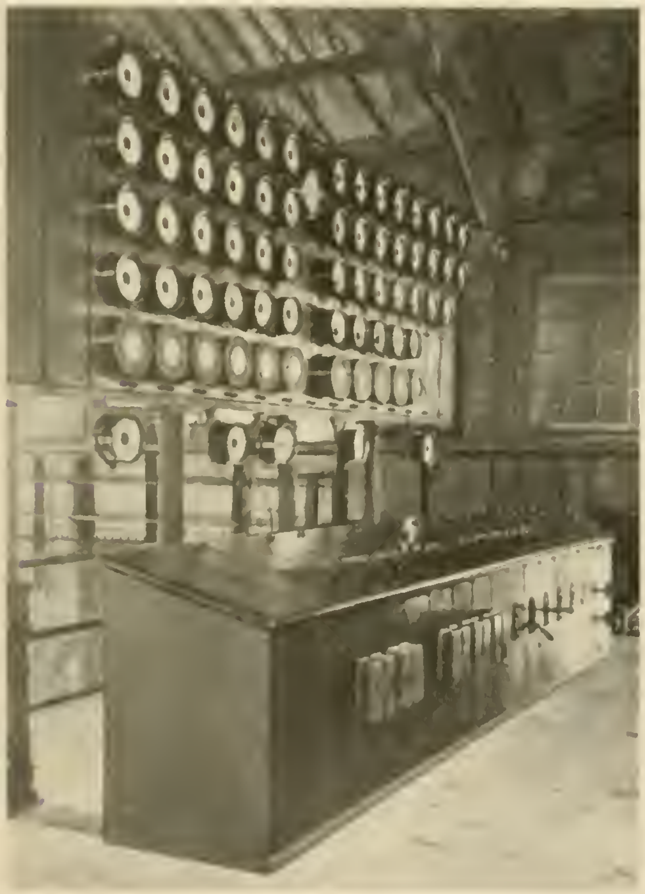


FIG. 4—LINEAR TYPE CONTROL DESK

The panel board, although the simplest in construction, may, because of its usually great length where applied to large stations, be much more difficult to operate than the desk control. It usually requires the least width and the greatest length as regards floor space and is, therefore, sometimes chosen in spite of other possible disadvantages, where a long, narrow gallery is the only provision which can conveniently be made for the switchboard. The open construction of wiring and control busses, as obtained by use of the panel board, is alone responsible for its adoption by many engineers.

It is desirable to arrange the panels to correspond with the wiring arrangement, if possible, as this is of considerable assistance to the operator by permitting the use of a dummy or mimic bus, or system of busses on the front of the panels, thus forming a single line diagram of the complete wiring system. The conduit system for arranging the control and instrument wiring is also greatly simplified. If, however, there are a great many circuits to be controlled and the arrangement is such that a number of feeders intervene between each generator panel, the generator panels become too widely separated to be under the immediate supervision of the operator and must be assembled at one end or at the center of the board or as an entirely separate board.

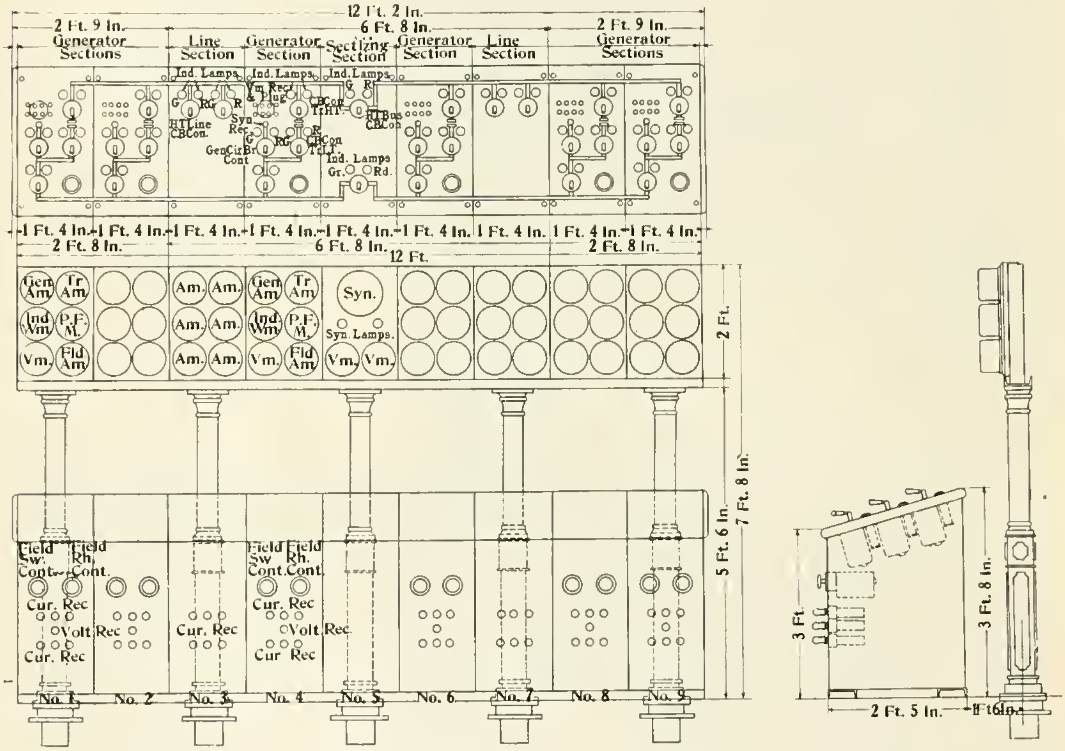


FIG. 5—TYPICAL CONTROL DESK AND INSTRUMENT BOARD DRAWING
Showing arrangement of meter receptacles and miniature bus.

THE CONTROL DESK

The combination control desk and elevated instrument board, as illustrated in Figs. 4 to 7 inclusive, may be used for stations of any capacity and any number of circuits. The particular form chosen, however, must depend upon the local conditions, as above described. For a small number of circuits the linear desk (Figs. 4 and 5) may be employed, while for a greater number of circuits the semi-circular desk (Fig. 7) is more desirable as it permits a uniform view of all sections of the desk from one central position.

When it is desired to use a wall of the building for supporting the instrument panels, the arrangement may be as shown in Fig. 1-b. The instrument wiring, except for a small amount beneath the desk, and all small, unsightly auxiliaries may thus be located in a separate room.

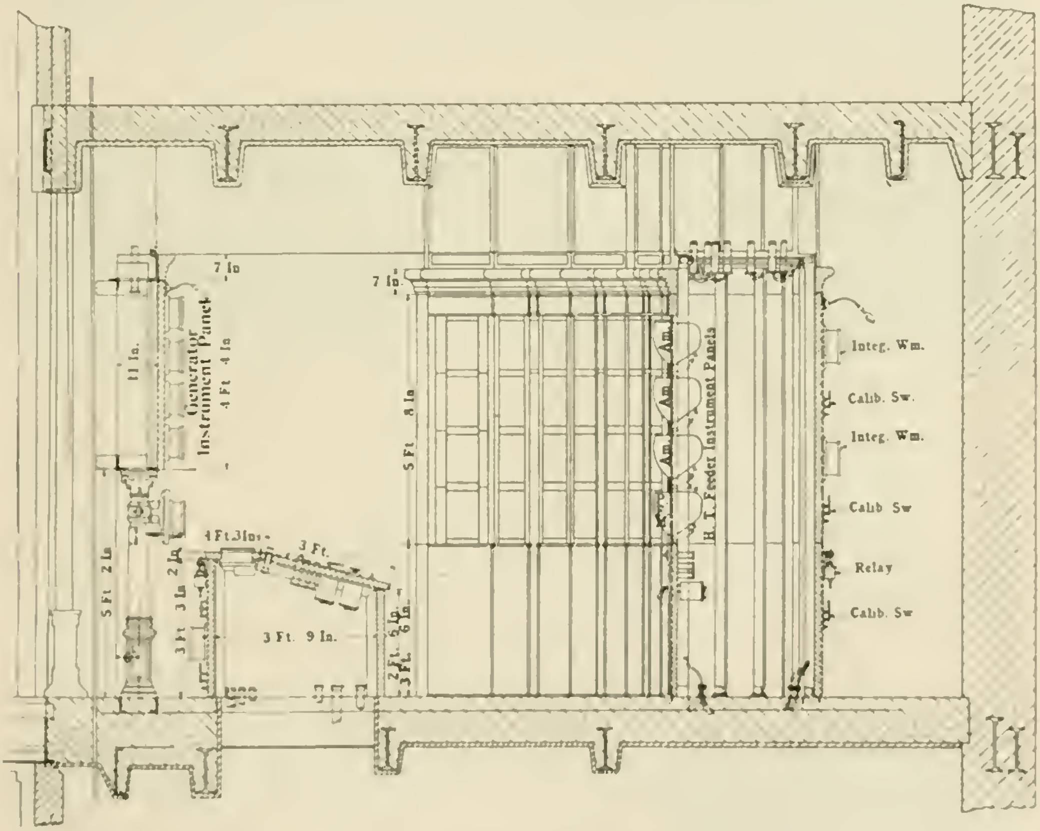


FIG. 6—CROSS-SECTIONAL DRAWING OF COMBINATION CONTROL DESK AND ELEVATED INSTRUMENT BOARD

For generator and bus tie circuits, with double semi-circular feeder board of the panel type.

Where there are few instruments and a very compact form of desks is desired, flush type instruments inserted in the top of the desks, as in Fig. 1-c, or standard instruments supported above the desk as in Fig. 1-d, may be used. The form shown in Fig. 1-e is the next step, where more instruments must be accomodated on the simplest form of board. In this form also the desk portion may be employed for generators only, while the feeders are accomodated on a continuation of the instrument section extending to the floor and arranged on each side of the generator sections.

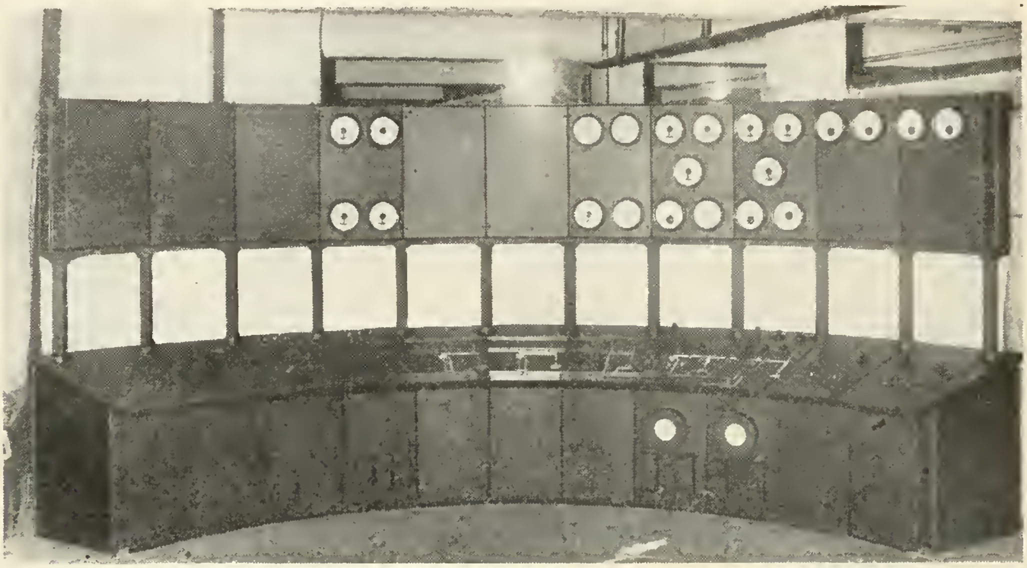


FIG. 7—CIRCULAR TYPE CONTROL DESK

Instrument panels supported on columns which form part of the desk framework.

Fig. 1-f may be employed where many relays and other auxiliaries must also be accomodated. With this arrangement the wiring on all panels may be entirely enclosed, at the same time making it very accessible. When it is considered desirable that the operator have an unobstructed view of the station floor while standing at his board in the gallery the forms shown in 1-g, 1-h and 1-i may be adopted. The wiring for the instruments is taken up through

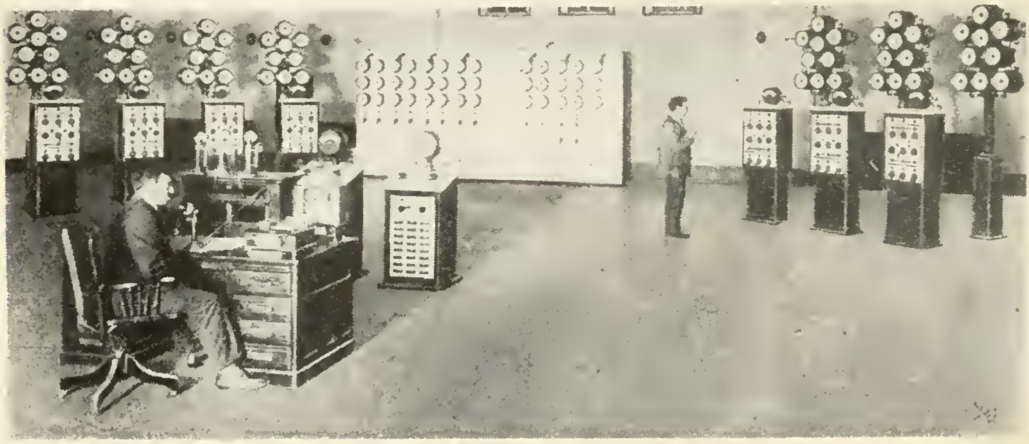


FIG. 8—COMBINATION PEDESTAL, POST AND PANEL EQUIPMENT

the columns supporting the instrument panels, which are covered at the back with expanded metal or sheet steel removable covers. The instrument columns, Fig. 1-l, may be arranged to form a part of the gallery railing where desired.

When the number of feeder circuits is very large as compared to the number of generator circuits, a very satisfactory arrangement may be obtained by the use of the arrangement shown in Figs. 1-j and 1-k. In the former, the switchboard is sometimes built in semi-circular form, where there is a great number of panels, so that all meters will face the operators desk. The arrangement shown in Fig. 1-k may be used when it is desired to control a great number of circuits in addition to the generator circuits from the control desk itself. The instruments are divided between the front and rear switchboard, the indicating and integrating meters, voltage regulators, testing receptacles, etc., being placed on the front board, with the relays, relay switches, and station auxiliary control which is operated infrequently, on the rear

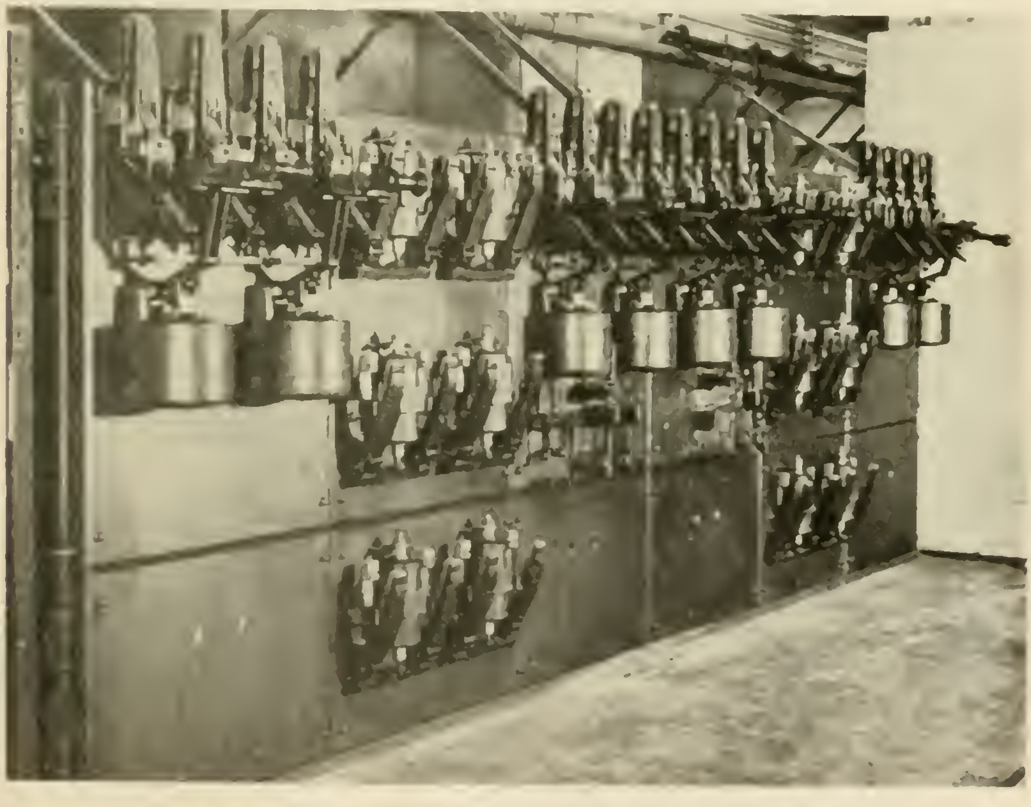


FIG. 9—ELECTRICALLY-OPERATED DOUBLE-THROW EXCITER BOARD

Containing double-pole, double-throw switches (panels 1, 3, 4 and 6) for four exciters and double-pole, double-throw field switches (panels 2 and 5) for six generator fields.

board. The ends are covered with grill work, provided with doors, thus forming an enclosed compartment containing the more unsightly parts of the board.

PEDESTALS AND POSTS

When a station is equipped with very large units, pedestals for the control switches and receptacles, with posts for supporting the instruments are sometimes used because of the complete individuality thus obtained for each unit. The chance of the operator mistaking the wrong control switches is greatly reduced and the chance of trouble in the small wiring communicating itself to more than one unit is minimized. This form of control may be used for the generators only, and perhaps for the transformer banks when used, while the feeders, which require less attention, are provided with a panel type of board.

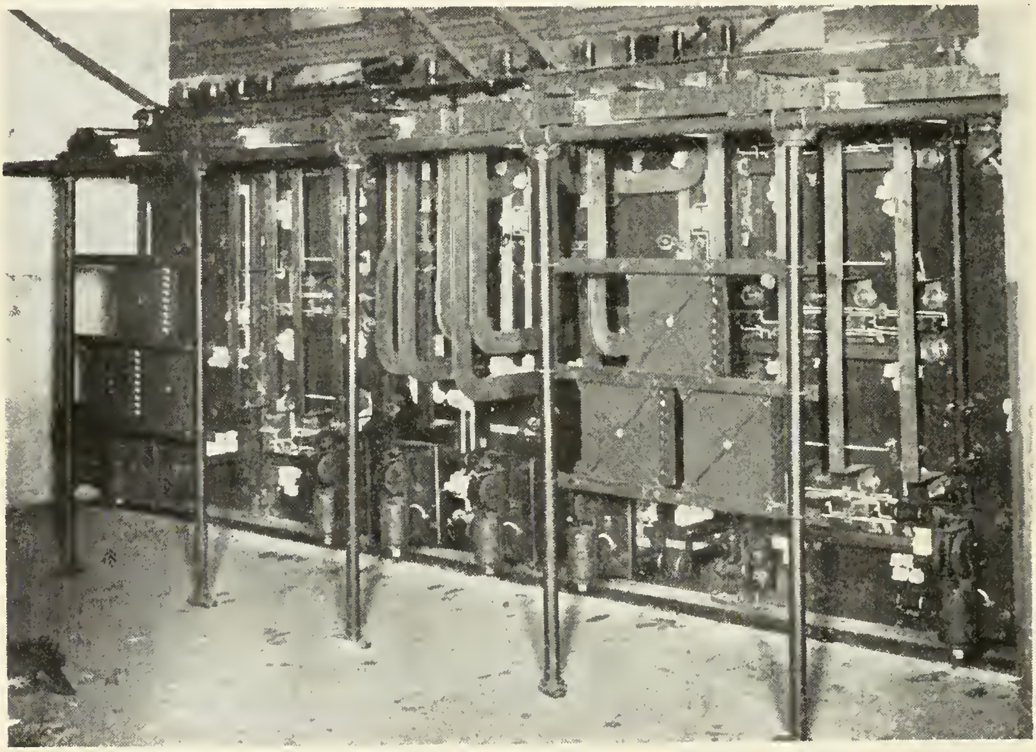


FIG. 10—REAR VIEW OF EXCITER BOARD SHOWN IN FIG. 9

THE VALUE OF PROCESS SPECIFICATIONS

T. D. LYNCH AND F. C. LYNCH

A shop process is any operation or series of operations which is performed in fabricating a raw material into a finished product. A process specification is a clear definite statement of these operations giving their sequence, the materials to be used and special notice of difficulties to be guarded against.

OWING to the failure of our progenitors to leave records of their work, we find ourselves unable to obtain products which were in common use centuries ago. To estimate the degree to which civilization has been retarded by the loss of these special processes would be impossible. No doubt, one of the greatest losses the world has ever known was the burning of the Library of Alexandria, which, it is believed, contained records of many of these lost arts. For many years research men have been trying to rediscover some of these, but with very little success. If such men could have started with the knowledge of the method used in the past, and spent their time and efforts in improving them, civilization would doubtless be centuries further advanced.

For a long time the secret process used in the manufacture of silks has been confined largely to the people of the East, and only a comparatively short time ago was given to the people of the West by individuals from the East. History tells us that James I of England smuggled three workmen into England from France to instruct the English workmen in the process of manufacturing alum which was used in dyeing. The secret of manufacturing soft porcelain was known by the great family of Medici in the sixteenth century, but was lost soon afterwards, because it was too carefully guarded. Our real porcelain was obtained first by an employee of Frederick Augustus, Elector of Saxony, in the year 1710. The secret was very closely guarded by building a factory in a forest and always keeping the drawbridge at the entrance raised; none but the workmen could enter and leave the factory, and they were bound by oath to keep the secret until death, if by accident they learned it. They were also taught that betrayal meant death. This was the origin of the famous Dresden or Meissen ware. The masterpieces of the pottery art which were produced in Vienna, were the result of a runaway workman carrying the secret to Vienna in 1745. In 1770 the secret was carried to France and the manufacture of Sevres pottery began.

These are only a few of the many examples which could be given to show how countries have in the past sustained enormous losses, either by their failure to keep records or because the work was so arranged as to prevent any one man from becoming familiar with the entire process.

Until recently, knowledge of processes has been in the possession of a few individuals. The course formerly followed by skilled workmen in almost every occupation, to keep their secret processes from being lost, was to train the oldest son in the trade of his father; in so doing they were sure that the processes would not be lost. At the present time, however, the burden of preserving and advancing shop processes has fallen upon the manufacturers themselves. Overcoming these difficulties and standardizing products are the two most important reasons for the process specification.

During the era of small shops, it was easy for the manufacturer to carry all processes in his mind. This worked no great hardship upon him, because even today, the foreman of any particular section soon has all the processes, which are more commonly used in his section, memorized to such an extent that it would not be hard for him to produce them in his own way and perhaps get the same results as the workman. After the next step taken by the industrial world, which was the formation of larger companies where the work was much more varied, it became impossible for one man to carry the work entirely in his mind. This immediately opened a new field for what has since been called "process engineering," of which the process specification is the product. Its influence on the manufacturing industries in the future will be very broad. Embraced in it are all the benefits resulting from standardization, which, as we know, in the case of machines, has resulted in a better and more useful product, as well as quick deliveries, all for a lower cost and lower investment in repair parts to be carried in stock. The same thing can be expected from the use of the process specification—a better, a more useful and a cheaper product, and the interchangeability of workmen, which will result in keeping the best workmen busy and thus a smaller number of better men on the payroll with the same output, eliminating the necessity of keeping one man for any particular operation. The possibility of losing valuable information when employees leave the company is also eliminated, since a record is always available, telling details of the operations and their sequence. This information is clearly the property of the company, as it is usually obtained through the expenditure of large amounts of time and money.

In almost all branches of engineering, records are among the most important parts of the science, and all constants are very carefully recorded for future use. The permanent recording of data by engineers is in quite a contrast to the procedure followed in some shops where large sums of money are spent to develop certain processes and no records kept of how the results are obtained, the records of the difficulties met and how overcome being only in the minds of the men in charge of the work. In time, these men leave the company and sooner or later the same difficulties are met by their successors, and, without any available records, it is necessary again to spend time and money finding the cause of the trouble and eliminating it.

The process required to manufacture the raw material and fabricate it into a finished product is intricate and usually the result of numerous operations. One does not realize how little he knows of a common every-day subject until he attempts to prepare a detailed written description. Most processes are a growth; each individual during its development has learned to do his part with great skill, and the whole series of operations has expanded until the work of many men is assembled to form a finished article of commerce. As long as each member of this network of trained men is on duty, the strength of specialization and unity of purpose is shown in the production of a good article, and at a low cost. But let a man performing a particular operation leave; the details of the work to be done are briefly described to the new incumbent. Work proceeds, production is pushed, but a little later trouble develops, which, as a rule, is very expensive. When the origin of this trouble is traced, it is usually found that the defect is in the part of the apparatus made by the new man, due to ignorance, unreliable information, a misunderstanding in the brief and incomplete description of his new work, or to the fact that the workman's ideas of the proper methods differ from those of his predecessor and he has incorporated his own ideas into the work. Original ideas are always to be encouraged, but the introduction of a new idea or plan without a comprehensive knowledge of the relation of the part in question to that of the whole, usually makes trouble.

Some efficient plan should be adopted for perpetuating efficient methods of doing things; modern managers with modern machinery demand interchangeability of men as well as interchangeability of parts of apparatus made in quantity. They further demand that work and materials be unified in different sections of the same works and at different works of the same company; for example, the composition and methods of making and using solder, or of making a cast iron bearing and lining it with babbitt, should be identically the same in materials, operations and the finished product, whether made in different parts of the same works or at different works of the same company.

Modern managers are relying upon process specifications for the solution of these difficulties in the manufacture of their varied products. In order to accomplish these results satisfactorily and efficiently, process specifications should contain concise, definite statements of the operations, their sequence and the materials to be used. Such specifications have standardized manufacturing operations so that irrespective of where the parts are manufactured, the engineer knows the data given will be satisfactory for the parts of any future machine.

Process engineering is the art of procuring the necessary information and describing definitely and fully the details of all the operations in their regular sequence necessary for proper production. The main work of process engineering may well be considered as that of procuring the facts in the form of a permanent record. Facts well in hand usually clear up the most difficult problem, and it is often surprising to find how simple the solution becomes. The keynote is to get the cold facts just as they are, study the problem, draw conclusions and write them into a process specification as a permanent, definite record.

When writing a process specification, both needs and means must be considered. Laboratory tests give a good clew to what is needed, and a start in the procuring of proper data. In this preparation of data comes the work of the process engineer. To be effective in getting true data, one must coöperate with the man who actually does the work; he knows how to do by doing, can demonstrate clearly and definitely, but rarely can he describe correctly any complete operation. He will furnish a great deal of dross and chaff, but with it will give many points of great value.

There are two principal ways of securing this required data. The one is to get the man who is doing the work to write it out himself in his own way, giving such data and in such form as it may come to him. This information must then be classified and put into final form by the process engineer. Tradesmen and mechanics will describe the operations performed just as they would tell them to a successor. Their intentions are good and their descriptions conscientiously given, but when these descriptions are written as given and afterwards returned to the author for his approval, it is almost invariably found that the meaning is not clear or it may be erroneous, so that many important changes are necessary—change this and change that—until finally we have an approved process, clear, definite, and a matter of permanent record.

The other, and usually the more efficient way of obtaining this data is for the process engineer to collect all the information obtainable by observation, questions, experiments, and personal contact with the work in progress, and put his own findings into final form. It is often necessary actually to do the things about which the description is to be written in order to make sure that no detail has been overlooked and that each explanation is complete. Data once established and carefully recorded may be handed down to a successor with the object of getting the work properly executed by the new incumbent. This serves the double purpose of instructing a new man on a piece of work, and of forming a firm foundation on which to build future developments and improvements.

Improvements are suggested from time to time and must be carefully considered, and such changes as are found to be advantageous must be incorporated in the specifications. Quite frequently it is necessary to develop a process from its inception, and this may include special apparatus as well as methods and materials. Such apparatus should always be substantially constructed, and yet the cost must be kept as low as is consistent with good results. Especially should care be taken in the building of the first equipment, and it should be thoroughly tried out under shop conditions. A heavy and costly piece of apparatus may and often does defeat a most excellent project.

It is considered infinitely the better plan to have the engineer who develops a new process and new apparatus in connection with it, supervise the design, installation and placing of the whole scheme in final commercial operation.

Shop foremen usually receive the specifications in a coöperative spirit, realizing that since they have helped to furnish the information they are a part of the specification and at the same time that the responsibility for the perfection of the finished product no longer rests entirely upon their judgment as to how it should be manufactured, but instead, upon their enforcement of the specification. Thus their position becomes one requiring executive ability rather than the knowledge of the details of all the various processes used in this department. It makes it much easier to start new men out in the work, since all men prefer to master the best method of performing an operation rather than to develop one of their own, realizing it will make them better workmen and thus able to command better wages. The ease of starting new men on the work allows interchangeability of workmen, which is a great help to the foremen, as in present manufacturing industries it often happens that first one and then another line of production is the most active. This interchangeability of workmen was almost impossible under the old conditions, since a workman did not approve of having another man working on his line and would not help get him started. The specifications also benefit the foreman, inasmuch as they are written to fit into the existing conditions of the shops and in that way he is not expected to manufacture products and get results for which he is not equipped.

From the shop viewpoint, a good specification is one which is exact, and does not contain any general statement requiring the judgment of the workmen to determine the exact condition. For example—a good specification should not say, "If solution is too thick, thin with approved thinner," but instead it should state the specific gravity at which the solution should be worked. For effectiveness in the shop, a specification should contain short sentences and common words which will be understood by any workman who can read.

All specifications should be kept up to date and to do this, a record of all that are issued should be kept on file and a receipt given by each foreman as received. To keep the specifications up to date necessitates following them very closely, because a change might first be arranged between the engineers and the shop organization as an experiment, and then adopted. Since this happens gradually it is liable to result in a change in the process without the revision of the records. Whenever a specification is written or revised, it should, before being approved, be sent to all departments doing this class of work and receive their approval and signatures, thus eliminating any possible dissatisfaction when placed in the shop. The foremen can then offer no excuse for not following in detail each operation described, since it has already received their approval. The inspection of the processes will result in better specifications, because the engineer, realizing that his descriptions will be followed in each detail, will be careful to see that each detail is correct; better products will result because the shop, realizing their work will be rejected if defective, will follow the instructions more carefully, and no important detail will be slighted; better material will be used because defects or inadaptability of any of the raw materials will be determined immediately and a different material specified.

The adoption of process specifications by the manufacturing industries means a more uniform product by standardization of methods employed, a permanent record containing valuable data for future improvements and the introduction of scientific men into a new field which has in the past been conducted largely by rule-of-thumb methods. Their investigations are first, to generalize the different processes, and then to seek the laws which they follow. The determination of these laws results in the elimination of the old rule-of-thumb methods, and the education of workmen along more scientific lines. Whole communities are profiting by the better education of individuals and the cheaper and better products resulting from the introduction of more scientific methods by process engineers.

SHOP TESTING OF ELECTRICAL APPARATUS—VIII

INDUSTRIAL SERIES AND HEAVILY COMPOUNDED MOTORS

METHODS of testing series and heavily compounded motors may be divided into two parts, the first including all motors of this type used for industrial purposes, and the second including all railway motors both direct and alternating current. The difference betwen the tests for these two types is mostly on account of the widely different character of service they are required to meet. All illustrative data for the first type given in the following text, was taken from the complete engineering test of a 25 horse-power, 800 volt, 650 r.p.m., series-wound mill motor.

RESISTANCES

The method of measuring the resistances, together with the data for temperature correction has already been outlined*; the results for the above motor are as follows:—

Armature at 16° C	0.3334	ohms
Series field at 16.5° C	0.471	ohms
Temperature Coefficient at 16° C	1.0355	
Temperature Coefficient at 16.5°C	1.0334	
Armature at 25°C = 0.3334 × 1.0335 =	0.345	ohms
Series field at 25°C = 0.471 × 1.0334 =	0.487	ohms

SPEED REGULATION

In this test the motor may be loaded either by belting or direct-connecting it to a generator of sufficient capacity to carry 150 percent rated motor load or by loading back on a similar motor running as a generator. The diagram of connections for such an arrangement is given in Fig. 1. With this scheme of connections the relation of the two as motor and generator may readily be reversed. Their direction of rotation may be changed by reversing the armatures of both machines. Each of these changes may be quickly made by properly connected double throw switches, care being taken that the voltmeter connections are changed to correspond in each case.

After the machines are connected up, their relative polarity is checked by circulating through both machines while they are still at standstill from one-half to three-fourths normal current by means of the booster. If the polarities are properly related the two machines will oppose each other as motors and will therefore remain at standstill; if not, their torques will be exerted in the same direction, causing the armatures to rotate. In the latter case the armature connections of one of the machines should be reversed.

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*The Electric Journal, Feb., 1913, p. 154.

After checking the connections carefully and inserting the necessary meters, as shown in Fig. 1, the motor should be started through a resistance, and as the latter is gradually cut out, care should be taken to note that the generator load is sufficient to keep the motor from reaching a dangerous speed. If the motor is compound-wound, the shunt field switch should always be closed before the machine is started. When the motor is running properly, the brushes should be set on the no-load neutral, as nearly as it can be readily approximated, and readings of speed taken at the same load for each direction of rotation. The brushes are then adjusted to such a position as to make these readings equal and, unless otherwise specified, they should be so set permanently. When the brush setting is permanent, that is, not capable of adjustment in the first place, the same readings should be taken and should check within 5 percent of each other, and of normal speed rating.

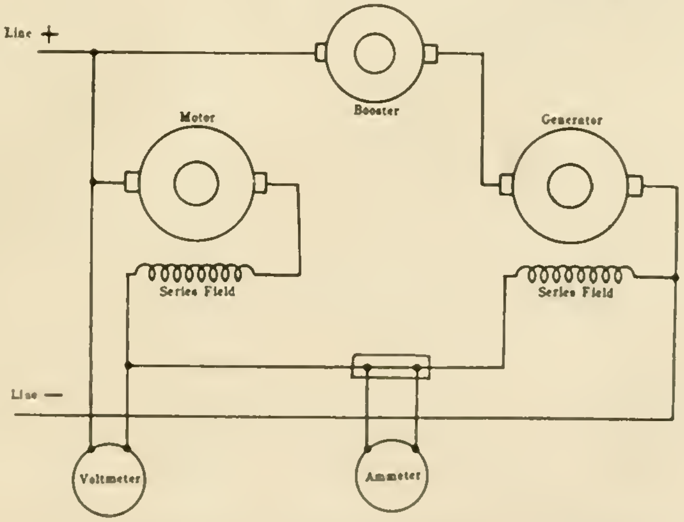

FIG. 1—DIAGRAM OF CONNECTIONS FOR LOADING-BACK METHOD OF TESTING SERIES MOTORS

With the brushes on the neutral point the motor is adjusted to the succesive loads desired, and at each one readings are taken of terminal volts, amperes, field volts and speed, and the commutation is noted. If the machine has a shunt field, its current should be that obtained at the end of a full load heat run. Readings should be taken for each direction of rotation covering a load range from 150 percent to as low a value as the increasing speed will permit with safety. It is usually best to start at the higher loads and come down to the lighter because of the resultant greater uniformity of temperature during the test. The readings for this test are given in Table I, and the speed regulation curves for each direction of rotation, are given in Fig. 2.

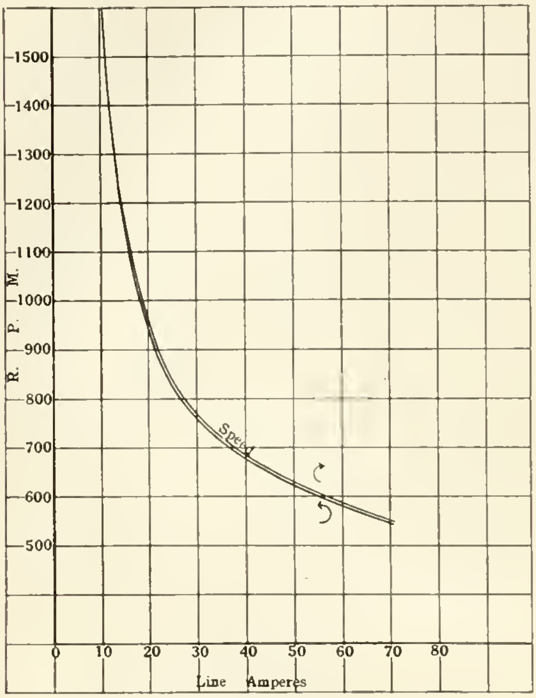

FIG. 2—SPEED REGULATION CURVES OF A 25 HORSE-POWER INDUSTRIAL SERIES MOTOR FOR BOTH DIRECTIONS OF ROTATION

Correction for Temperature or Voltage—The curves in Fig. 2 are accurate only at the temperature at which the test is taken as the potential drops in the motor circuit vary with the temperature. It is seldom necessary or desirable to make corrections in test results for this variation but when it is the following method is the simplest and most accurate:—

Let E = Terminal volts.
I = Terminal amperes.
r = Armature resistance at the desired temperature.
r_1 = Series field resistance at the desired temperature.
R = Total resistance = $r + r_1$.
e = Field volts as obtained by test.
$K = \frac{R}{r_1}$ ratio of total drop to field volts
Then e_1 = Calculated total drop = $I \times R$.
e_2 = Observed total drop = $K \times e$.
E_1 = Calculated induced volts = $E - e_1$.
E_2 = Observed induced volts = $E - e_2$.
Speed at the desired temperature equals observed speed times the ratio $E_1 \div E_2$

The value of the constant K for a given temperature can be readily calculated by correcting R and r_1 for temperature as indicated at the beginning of this article. Assuming that the desired temperature is 60 degrees C., the calculation would be as follows:—

Resistance at 25° C.	At 60° C.
Armature (r) = 0.345 ohms	0.3935 ohms
Series field (r_1) = 0.487 ohms	0.5555 ohms
Total resistance (R) = r + r_1	0.9490 ohms

$$K = \frac{R}{r_1} = \frac{0.9490}{0.5555} = 1.708$$

The ratio $E_1 \div E_2$ then follows directly, as indicated above, and may be applied to the values of speed in Table I. This same method may be used for making corrections in speed for different terminal voltages by substituting the desired voltage instead of actual line voltage when working up the calculated induced volts, E_1. The result will be only approximately correct on account of the difference in saturation at the different voltages.

TABLE I—SPEED REGULATION.

Volts.	Amperes.	Field Volts.	R.P.M.
Clockwise Rotation.			
500	67.5	40.5	552
500	56.25	35	592
500	45	29	646
500	33.75	22	723
500	22.5	14.8	879
500	11.25	7.3	1 500
Counter Clockwise Rotation.			
500	67.5	40.5	548
500	56.26	34	589
500	45	27	640
500	33.75	20.5	720
500	22.5	13.6	860
500	11.37	7.8	1 465

CORE LOSS, FRICTION AND WINDAGE

In this test the motor is connected up for separate excitation as in Fig. 3. Field current values are then obtained by means of the booster, varying from 200 percent normal to the lowest safe value, a sufficient number of points being selected to obtain an accurate curve. At each value of field current the armature voltage is so adjusted as to give the motor speed corresponding to that field as obtained from the speed curve. Core loss is proportional to the induced e.m.f. which, in turn, is proportional to the speed. Therefore, if for a certain field excitation, the speed is adjusted to the value found on the speed curve for that value of field current, the core loss will closely approximate that existing under load conditions, the only difference being that due to the effect of armature reaction under load.

It is best to start the motor under full load conditions, closing the armature circuit through a resistance and bringing the motor to speed. The field current is then adjusted to the first point desired on the curve and the speed regulated accordingly. At each point, values of line amperes, volts, field amperes and speed are read, giving in this case, the values in Table II. The results are plotted in Fig. 4.

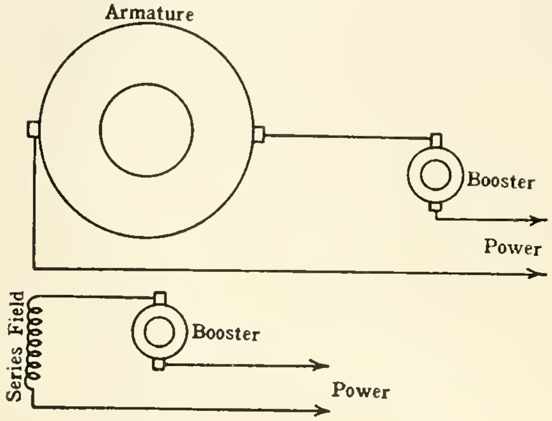

FIG. 3—CONNECTION DIAGRAM FOR TAKING CORE LOSS ON A SERIES MOTOR

FRICTION AND WINDAGE

In taking this test the the mechanical operation of the motor should be carefully noted. The oil rings should be carrying oil, the brushes set at the right tension, the commutator smooth, and the armature rotating without end play. The motor is then driven without load, the voltage applied being sufficient only to give it the required speeds. The data taken should cover the entire speed range of the motor, readings being taken at each point of line amperes, line volts and speed. This test should be taken before and after the core loss test and should give the same result in each case. Data for a four point curve covering the motor speed range is given in Table III, and the resultant curve is plotted in Fig. 4.

TABLE II—CORE LOSS, FRICTION AND WINDAGE

Volts.	Armature Amperes.	Watts.	Series Field Amperes.	R. P. M.
492.5	5.6	2 758	8	2 100
483.5	2.8	1 354	15.8	1 115
785	2.45	1 163	24.6	860
467	2.5	1 167	33.2	740
458	2.6	1 191	42	665
450.5	2.7	1 217	50	630
436	2.9	1 263	65	670

SATURATION

Readings of field current, speed and armature volts obtained in the core loss test furnish all the necessary data for a saturation curve. However, instead of plotting the relation between field current and voltage directly, it is convenient in the case of series motors to plot a curve showing the relation between r.p.m. and field current on the same sheet with the core-loss curve. The relation between field current and armature volts at any speed can then be obtained directly from the curves in Fig. 4.

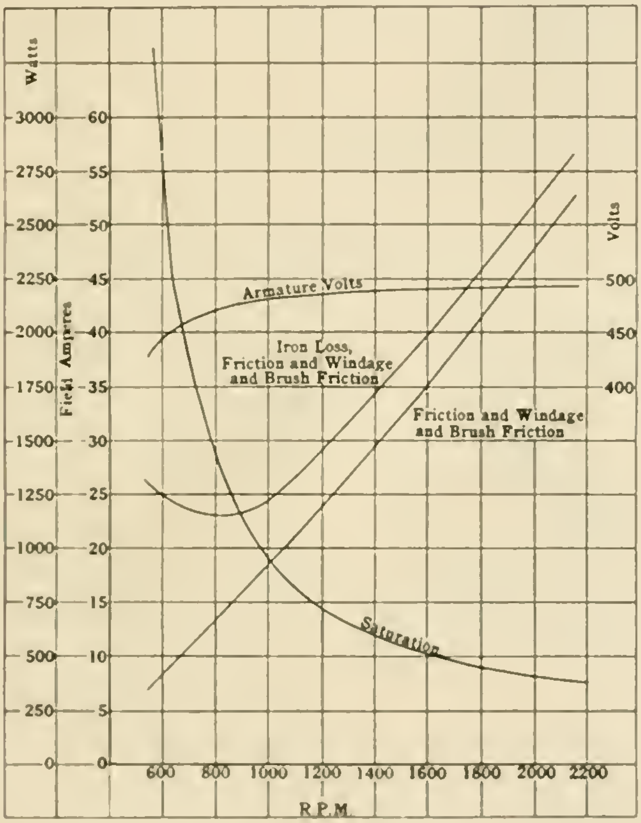

FIG. 4—SATURATION AND NO-LOAD LOSS CURVES OF AN INDUSTRIAL SERIES MOTOR

EFFICIENCY

There are three standard methods of determining the efficiency of series motors, the separate loss method, the Prony brake method and the output-input method for motor-generator sets composed of two similar motors. The first of these is, however, best adapted for general testing, the others applying usually to special cases.

TABLE III—FRICTION AND WINDAGE

Volts	Amperes	Watts	R.P.M
85	4.8	408	600
115	5.85	673	800
160	5.6	1 056	1 100
300	8.1	2 430	2 020

Efficiency by Losses—This is the most common means of measuring the efficiency of series motors and is carried out in the same manner as for shunt motors already outlined in Article VII.

With series motors the total value of core-loss, friction, windage and brush friction losses should be taken from the loss curve as in Fig. 4, the speed under consideration determining the point at which they should be taken for each point on the efficiency curve. The speed values may be determined either from the speed regulation curve, Fig. 2, or the saturation curve in Fig. 4. For convenience this curve may be plotted on the speed regulation curve sheet with line amperes as abscissae.

Efficiency by Brake—This method for series motors is exactly the same as that described in article VII for shunt and compound motors.

Input-Output—In this test two similar motors are coupled together as a motor-generator set. Care should be taken in lining up that there is no binding in the bearings and that the machines have sufficient allowance for end-play. The diagram of connections is given in Fig. 5, showing the generator series field in the motor circuit to insure the same excitation for both machines.

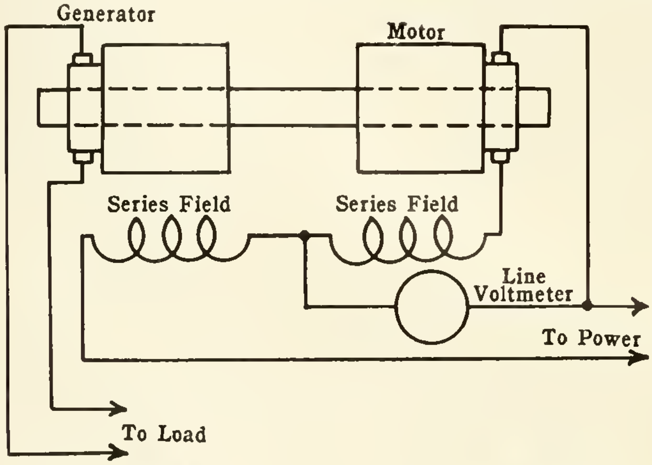

FIG. 5—DIAGRAM OF CONNECTION FOR MEASURING THE EFFICIENCY OF SERIES MOTORS BY INPUT-OUTPUT METHOD

Before starting, the cold resistances of motor armature and series field and generator armature should be taken. The brushes are then set on neutral and the motor started through a series resistance, care being taken that the generator is loaded on a suitable resistance, as the starting resistance is gradually cut out.

Starting at 150 percent normal load and decreasing by 25 percent steps, readings are taken at each point, of motor terminal volts and amperes, generator volts and amperes, and speed. Commutation should be noted during the test and, at the end, hot resistances of all windings taken as rapidly as possible.

In calculating the results of this test it is evident that the efficiency of the set is equal to the product of voltage and current on the generator end divided by the product of voltage and current on the motor end. Then, as the two machines are assumed to be similar in all respects, the efficiency of either will be the square root of the overall efficiency of the set. This method is theoretically subject to a slight error due to the fact that the machine operating as a generator is not running under normal conditions; but the error so introduced is small as compared to the possible inaccuracies of the method itself due to the fact that the two machines are not exact duplicates. Input-output tests for efficiency are not to be recommended except where approximate values only are desired.

TEMPERATURE TESTS

Because of the great variety of the service to which series motors are put, temperature conditions vary almost with the individual machine. For this reason no temperature test is standard, each test being determined to fit a particular case. However, when the conditions under which the test is to be run have been specified, the method of test is the same as outlined in Article VII for shunt and compound-wound motors.

COMMERCIAL TESTS

In running commercial tests on a series or heavily compounded industrial motor, a generator capable of carrying 125 percent motor load should be used as a load. Because of the heavy service for which they are intended, the mechanical details of series motors should be inspected with especial care before starting the test. The bearings should be well filled with oil and the shaft turning smoothly; and the brushes should be ground to a good fit.

Readings of speed, line volts, line amperes, series field drop and commutating field drop (if the motor has such a winding) should be taken for each direction of rotation at the 50, 100 and 125 percent values of load. These readings will serve as a sufficient check with the motors of the same lot on which complete engineering tests have been run.

Overspeed—The usual overspeed test on motors of this type is four times normal speed rating. The machine should be run without load as a series motor with only sufficient voltage to give the required speed. Care should be taken that the initial voltage applied is sufficiently low so that the speed will be well within the limit.

Leakage—The leakage or ground test consists of determining the insulation resistance by the series voltmeter method. It should be taken immediately after the over-speed test, as the insulation is more liable to show defective then than at any other time. Normal voltage should be used at first and if the voltmeter reading is less than 100 volts on a 500 volt machine it will be safe to make the over-potential test. This is usually 1 500 volts for 500 volt machines.

VEHICLE MOTORS

Complete engineering tests on vehicle motors are similar to those already described for series motors. Their commercial tests, however, are somewhat different.

Commercial Test—The motor bearings should be first filled with oil and the brushes carefully ground to a good fit and given a slightly backward lead, the armature rotating clockwise unless especially specified otherwise, as these motors are designed for one direction of rotation only. The motor is then belted or direct-connected to a generator of sufficient capacity to furnish 200 percent motor load. In starting these motors, the field winding is usually divided into two parallel circuits to give a greater starting torque, the change from parallel to series arrangement being made upon reaching a sufficient speed.

On reaching full load, readings of speed, armature volts, line amperes, field volts and field amperes are taken and commutation and noise noted. If these values are within the limits of the engineering test, the motor is loaded to 200 percent normal and given an observation half hour run, readings as given above for full load being taken at the beginning and at the end of the run. The full load speed should be checked again after this run, and the motor then shut down and the belt or coupling removed. With no load on the motor, sufficient current is shunted from the armature through a suitable resistance to give, with normal field and voltage, the normal full load speed as found above. Readings are then taken of armature volts, armature amperes, field volts, field amperes and speed. Then the product of armature volts and armature amperes gives the no-load losses of the motor.

The motor is now shut down and the over potential test to ground made. For this type of motor 1000 volts to ground for one minute is a sufficient test.

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943—Phasing Out Generators—A 360 k.v.a., 2200 volt, two-phase generator was phased out by placing transformers across the open oil switch as shown in Fig. 943 (a). With no voltage on the generator, all four lamps glowed at about one-half voltage, but when the field was excited, lamps *2*, *3* and *4* glowed in unison, while *1* remained unaffected. No. *2*, although keeping synchronism with *3* and *4*, showed a very excessive voltage, so that it was impossible to bring the generator up to full voltage without bursting the lamp. Many variations of this method were tried, the transformers were changed, etc., but the same result was invariably observed. As time was pressing, this generator was phased out by means of a motor, found to be correct, and put into service. Two other generators in the same power house were phased out with identically the same transformers and nothing abnoral occurred. It may be mentioned, that while this generator was being phased out, the static ground detector on phase *A B* swung from side to side with a frequency corresponding to the beats of lamps *2*, *3* and *4*, thus suggesting that the equalizing current was flowing through the ground detector instead of through lamp *1*. Is it possible that a ground on the alternator may have caused transformer No. 1 to be shunted by the capacity of the ground detector in such a way as to set up resonance and cause the transformer to carry a constant current independant of the voltege developed by the incoming machine?

J. P. (ALBERTA)

The most probable explanation of the conditions described is the presence of a ground (or at least a partial ground) on the incoming generator at or near the terminal which will be connected to the bus bar *A*. If we assume a dead ground on this terminal and also a ground at the neutral of the system, a moment's reflection will make it evident that the potential across lamp *1* will remain constant at the value as caused by the voltage of the system; while that across lamp *2* will fluctuate from one-half voltage to one and one-half voltage, providing the incoming generator is operating at the same potential as the system. The effect of the static capacity of the system will be sufficient to cause the neutral to assume and maintain ground poten-

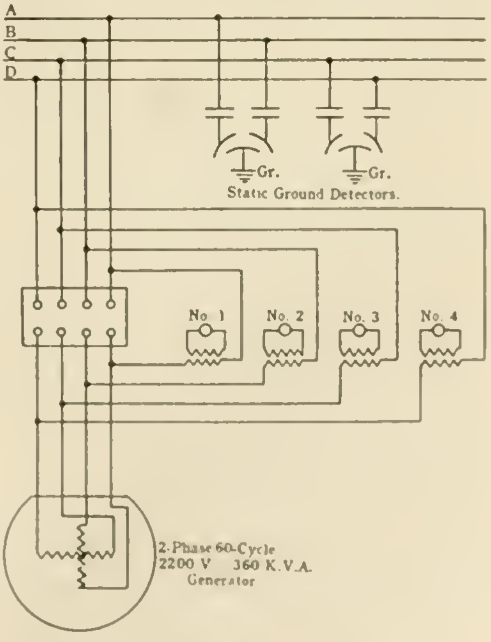

FIG. 943 (a)

tial in so far as the small current required for synchronous lamps is concerned. In other words, it will probably take considerable more than the current required for operating the synchronizing lamps to remove materially the potential of the neutral point of the system from ground potential. Hence, the assumption that the system is grounded at the neutral is correct in so far as the amount of current required for synchronizing is concerned. The only additional assumption, therefore, to account for the condition described in the foregoing question, is that of a ground on the terminal of the generator. That this is the correct explanation is also indicated by the action of the ground detectors, and again by the fact that the other generators were synchronized without this phenomonon appearing. P. M. L.

944—Power-Factor of Generator—Should the power-factor meter on a generator lag or lead when the generator is over excited, the power factor of the line supplied by the generator, being lagging? G. T. B. (WISCONSIN)

The degree of excitation of a generator determines nothing but the voltage when the machine is operated alone, and the power-factor is determined solely by the load. When the generator is operating in parallel with others, with a load of unity power-factor, the power-factor in the individual generator will be leading when the generator is under excited and lagging when it is over excited. If the load is lagging, the actual power-factor in the generator will be the vectorial resultant of the lag of the load and the inherent lead or lag of the generator, and hence may be either leading or lagging, depending upon circumstances. C. R. R.

945—Mine Equipment—The Lighting Company with which I am connected is negotiating with a coal mine in this vicinity with the intention of serving them with energy. The maximum amount of bituminous coal mined per day is about 500 tons, the working day is 8 hours, 6 days per week. The transmission line is 3 miles long at 2 300 volts, two-phase, 60 cycles. It is our intention either to use a synchronous motor direct-connected to a direct current 250 volt generator or a rotary converter; and we would like to know the relative merits of each. The equipment is as follows: One mining locomotive, approximating 6 tons, estimated at 40 hp., capable of handling 25 to 30 acres, total weight 3 500 lbs., on a one percent grade. One mining machine (short wall) estimated at 25 hp. They are now using a battery locomotive, capable of gathering 7 or 8 cars from the rooms to the main line. This locomotive is charged each night by a 7.5 kw, 110-volt generator at a 50 ampere rate. They also have a 5 hp motor for a 5 foot propellor fan. We could generate at the sub-station at such a voltage as to allow 8 to 10 percent transmission loss and supply a motor for the motor-generator set with 2 300 volts. The generator now on hand could be used during the day as an exciter for the synchronous motor and also charge the storage battery at night, being driven by a motor of a sufficient size to take care of the fan also. There will be no need of wire service in the form of trolley within the mine, as the locomotive will be purely a trip locomotive, taking care of the loads from the mouth of the mine to the tipple, a distance of about three-fourths of a mile. Would a vector diagram be applicable to this problem so as to see the advantage of changing any one factor, entering into the synchronous motor proposition? F. G. F. (W. VA.)

For mine service a synchronous motor generator set is slightly preferable to a rotary converter due to the better compounding characteristims. A rotary converter will be slightly more efficient than the motor generator set. The capacity should be about 50 kw to take care of maximum overloads, which may reach as high a value as 80 kw, when the locomotive is starting a load and the mining machine is running. It will not be necessary to use the small 110 volt generator to excite the synchronous motor, since this motor can be excited from the 250 volt generator. We would not recommend using the same motor to drive the small battery charging generator and ventilating fan, since the fan will run all the time, while the generator will only operate a few hours out of the twenty-four. Both the fan and the small generator should be driven by an induction motor, which should be 220 or 440 volt, since it is not practical to build a 2 300 volt motor for a capacity less than 20 hp. A vector diagram would be of little use except to determine the instantaneous value of power-factor by combining the load of the motor generator set, say at 100 percent power-factor, with the small motor load at about 80 percent power-factor. Since the load on the motor generator set is always changing the result would be of very little value. G. B.

946—**Exciter Brushes**—We have two motor generators, consisting of 23 horse-power, 3-phase, 60 cycle, 440 volt, 28.5 ampere, squirrel-cage motors direct connected to 120 volt, 125 ampere, 1 130 r.p.m. compound wound generators used for excitation purposes, for a 500 and 1 000 k.v.a. steam turbine driven alternator. The exciters are run a little over rated speed and furnish a current of from 60 to 90 volts regulated by a Tirril regulator. One of the exciters is placed by each machine; the larger machine being slightly out of balance causes a certain amount of vibration which was thought to be the cause of its exciter giving trouble. For about a month the exciter brushes sparked considerably, but by shifting them forward and back and checking the spacing we have them adjusted to give no sparking from no load to full load with the exception of one set of seven brushes which run all right until they pick up a piece of copper, then they spark untily it is removed. All of the bars on the commutator show a small surface (about one-eighth of the face) that is pitted us if arcing was going on. Also about one-third of the face of the brush appears rough although repeatedly surfaced off. The commutator has been sanded and put in good shape, but soon takes on this roughened appearance. The mica seems to be worn down to the level of the copper. (a) Would the vibration of the generator cause this trouble? (b) would graphite brushes or softer carbon brushes and more brush spring give better result? (c) Are the brushes too wide or not wide enough? C. I. H. (KANSAS)

The commutation of a direct-current generator will be made worse by any of the following changes: Increasing of vibration; increasing the speed; high mica; improper adjustment of brushes. The description of the trouble with this machine indicates that there is sparking at the brushes which causes a marking of the commutator bars and also the brushes. If the vibration of the machine is bad, it might account for the trouble; at any rate, it would have an injurious effect on the commutation. Softer brushes would not necessarily improve the conditions, but a high grade brush, such as are manufactured by all the carbon makers, would be advisable. The marking of the bars and brush indicates that the brush is too wide. The face of the brush could be slightly bevelled so as to try out the effect of a narrower brush contact. It would probably be advisable to undercut the mica. D. H.

947—**Power-Factor Reading**—In a station containing three two-phase, four wire, 2 260 volt, 55 ampere per terminal, 60 cycle generators, two additional power factor meters have been installed, making one for each unit where formerly there was one meter for all. What is the formula for finding the resultant of the three-power factor meter readings which are taken every hour with the watt and ampere readings?

W. T. M. (PENNA.)

It is impossible to determine a resultant of different power-factor readings from the readings of the power-factor meters only, as the result depends also upon the amount of power conveyed at each of the different power-factors. The resultant power-factor may readily be determined by dividing the total kw. output by the total k.v.a. output. For best results the generator fields should be adjusted until all the meters read the same. C. R. R.

948—Emergency Transformer Connection—Why is it desirable to to short-circuit the damaged windings of a three-phase shell type transformer when they are disconected from the working circuits. V. S. F. (NEW YORK)

If the damaged windings are not short-circuited the full normal e.m.f. is generated in them, and since the coil insulation is defective, an arc is liable to be started which might burn up the rest of the transformer. If the damaged winding is short-circuited on itself the generator potential will be limited to a very small drop through the windings caused by the comparatively small current, as explained on page 417 of the May, 1913 JOURNAL. C. R.R.

949—Determination of Polarity—Is there a method in use by electricians for determining the polarity of electric current? G. W. K. (N. DAKOTA)

A quite common method of determining polarity is to dip a wire from each of the terminals of the battery or generator into salt water a short distance apart. Bubbles will arise from around the negative terminals. If the current is flowing the polarity may also be determined by means of a compass. Set the compass over the wire, with the wire in such a position that when no current is flowing it will be parallel with the needle of the compass. If the north end of the compass is deflected eastward, the current is flowing toward the north; if it is deflected westward, the current is flowing in the opposite direction. There are also various small instruments for sale by the electrical supply houses for determining polarity. The best method is to use a direct-current voltmeter, if one is available. J. W. M.

950—Operating Rotary Converters by Two Transformers—We are now operating a six-phase rotary converter from three single-phase transformers, 33 000 volts, three-phase delta to 435 volts, six-phase diametrical, with 129 volts for starting. Please show by diagram how to connect this converter so as to operate it from two of these transformers. J. O T. (ILL.)

A diagram is unnecessary for this connection. Simply disconnect one transformer, leaving the others connected as they are at present. However, this will give improper electrical and magnetic conditions in the armature, the result being a compromise between single-phase and a balanced polyphase system. J. L. Y.

951—Governor Trouble—We have a 100 k.v.a., 240 volt alternator direct connected to a high speed engine to which is belted an exciter. The governor on this engine is very sensitive, any sudden change in load causing the engine to race and hunt about five percent above and below normal speed. We use a Tirrill regulator, but when the engine starts to race the voltage varies about 10 volts above and below normal. The exciter has a capacity of 10 kw and is a shunt wound commutating pole machine. (a) Do you think there is any way to remedy this trouble outside of the engine governor? (b) Do you think the use of a current transformer in the generator leads would help, it being connected to the compensating winding of the regulator? F. W. L. (WASH.)

(a) No. The engine governor is apparently wholly at fault. The sensitiveness of the engine governor should be retarded very materially by its dash pot or other means, as with the engine governor as sensitive as indicated, neither the engine nor the Tirrill regulator is allowed to do its work properly. The engine should be adjusted so that there will be no tendency to hunt under any condition of load. The dash pot of the Tirrill regulator should then be adjusted to a point just free enough to prevent any hunting. This will give the proper and best operating conditions. (b) No. The addition of a current transformer would not improve matters unless there is a line loss from the switchboard to the center of distribution. In this case, the regulator could be adjusted to overcome this loss only, but the system being only 240 volts, it seems rather evident that the switchboard was, in this case, the center of distribution. Compensation for line drop is not necessary, and as above stated, it would not improve matters as regards the hunting of the engine or the voltage being regulated. A. A. T.

PERSONALS

Mr. John F. Wallace, president of Westinghouse Church Kerr & Company, has been selected as the expert adviser of the committee on railway terminals of the City Council of Chicago.

Mr. R. H. Henderson, works manager of the Westinghouse Lamp Company, has resigned. His successor is Mr. H. S. Black, formerly manager of the St. Louis Mazda Lamp Works of the General Electric Company.

Mr. Harold W. Smith has recently been appointed electrical engineer to the department of home affairs, Commonwealth Government of Australia, with headquarters at Melbourne, where he has charge of electrical work in coast defenses, dockyards, quarantine stations, etc., and also all electric work in the federal territory. An area of 900 square miles has been reserved by the commonwealth on a plan similar to the District of Columbia, and the federal capital, Canberra, is being built.

Mr. W. H. Williams, formerly in the Pittsburgh office of the Electric Controller & Mfg. Company, has been transferred to the Chicago Office with the same company to assume the duties of district manager in Chicago territory.

Mr. G. E. Emmons, general manager of the Schenectady Works of the General Electric Company, has been placed in general executive charge of all manufacturing operations of the Company. Mr. Emmons has been in the employ of this Company for 28 years.

America e Industrias Americanas, New York, for July, contains a reprint of the article by Mr. H. K. Hardcastle, entitled "The Modern Mine Locomotive" from the JOURNAL for March.

Industrial Engineering for July reprints the article by Mr. D. C. Pultney, entitled "Safeguarding Motor-Driven Apparatus" from the JOURNAL for June.

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NEW BOOKS

"Railroad Operating Costs." 144 pages, 64 illustrations. Published by Suffern & Son, New York City. Price, $2.00.

Too frequently operating costs are viewed in the abstract with the result that they prove of very little instructive value. As pointed out in Chapter I of this interesting volume, the important information to be had from the vast amount of data and reports filed annually with the Interstate Commerce Commission, is virtually lost, as it is not prepared in a way that establishes concrete and useful comparisons. The publishers have taken this great store of information as a basis for determining the characteristic elements of operation of over fifty of the prominent steam railroads, and have collected the various ratios and percentages which play an important part in the final results. As common references were desirable, units of comparison, such as the capitalization per mile of road operated, and gross earnings similarly; population per mile of road, density freight and passenger traffic per mile of road; operating ratios and the relative percentages of conducting transportation, maintenance of way, maintenance of equipment and general expenses, etc., have been effectively compiled. The effect of topography of the region traversed has been examined, in so far as circumstances allow, and deductions thereon presented. Other pertinent conditions are analyzed and parallelisms are shown, as likewise disparities, where they may occur. An excellent purpose has been served by this book in making a critical digest of the essential operating data. It has already been subjected to a call for a second edition, in which has been added a valuable chapter on fuel. F.D.P.

"Fourth Annual Report of the Board of Supervising Engineers, Chicago Traction." 523 pages, illustrated. Published by the Board.

The fourth report covering the fiscal year ended January 31, 1911, has recently been put out in bound form. Along with a great mass of detail, this book gives much very valuable data, especially with reference to electrical transmission and distribution, power plant and sub-station equipment, cars and their operation, and tunnels and viaducts. There is, in addition, a great deal of statistical information which should be of interest to operators of electric railway and power companies.

ILLUMINATING ENGINEERING SOCIETY CONVENTION

It has been definitely decided to make the Hotel Schenley the headquarters of the Illuminating Engineering Society Convention which will be held in Pittsburgh, September 22 to 26. This is a peculiarly fitting selection as the Hotel is in a popular residence section which is rapidly becoming a civic center. It is in easy walking distance of the Carnegie Museum and Library, Carnegie Technical Schools, University of Pittsburgh, several prominent clubs, and the Soldiers' Memorial Hall. The last mentioned building will prove of particular interest to illuminating engineers because of the wonderful lighting effects used therein, which are said to be unequaled anywhere in the United States. The program as outlined at the present time covers an exceedingly interesting set of papers on the various subjects pertaining to illumination.

In addition to the technical sessions of the society, the local committee has arranged for a series of entertainment features in which the ladies are included. These features cover golf, tennis, baseball game, automobile rides, theatre and card parties, and conclude with a banquet at the Hotel Schenley at which some innovations are promised.

Inspection trips have been arranged to several industrial plants, including the Westinghouse Electric & Mfg. Company, Macbeth-Evans Glass Company, and the Carnegie Steel Company; also a luncheon at the H. J. Heinz Company for the ladies.

The papers as scheduled at this time include, among a number of other subjects, the Quartz Light, Fontune, and Neon Tube; Church, Factory, Store, Hospital and Street Car Lighting, the Present Commercial Development in several forms of Lighting, Errors in Photometric Measurement, and the History of Artificial Lighting. In addition to these, a number of others on equally interesting subjects will be presented by authors well known to the engineering profession in illuminating as well as other fields. The development of the new flame carbon arc lamp will also be discussed by representatives of the manufacturing concerns. An interesting feature in connection with the technical session will be the holding of symposiums on the various general subjects, to be led by those particularly well posted on the different subjects. These meetings will afford an opportunity for free and open discussion that it probably would not be possible to obtain in a more formal meeting.

A transportation committee has been appointed consisting in part of the secretary of the local section in each city which will perfect arrangements for the members and friends in obtaining transportation to and from Pittsburgh.

The time selected for the convention is a particular fitting one inasmuch as at that time the City of Pittsburgh will be celebrating the 125th anniversary of Allegheny county and will be decorated accordingly. This means that the visitors will be able to see Pittsburgh in its holiday attire and witness many special illuminating features.

The papers committee, although not prepared to announce the entire program, advises that the following papers have been secured: "The Use of the Photo-Electric Cell in Photometry," by Prof. T. R. Richtmeyer, of the department of physics, Cornell University; "Characteristics of Enclosing Glassware," by Mr. V. R. Lansingh; "The Quartz Mercury Vapor Lamp and Its Applications," by Mr. W. A. D. Evans, of the Cooper-Hewitt Electric Company; "The Fontune Lamp as a Working Standard," by Messrs. E. G. Crittenden and A. H. Taylor, of the Bureau of Standards, Washington, D. C.; "The Neon Tube Lamp," by M. Georges Claude, of Boulogne, France. In addition to these, Mr. Roscoe Scott, of the Nelite Works of the General Electric Company, Cleveland, Ohio, will deliver a lecture on the Evolution of Illuminants. Coming, as it does, at a time when lighting standards are being changed so rapidly with a greatly increasing use of artificial illumination, this discourse should prove of particular interest in describing the progress of the art. The Philadelphia section intends to present to the presiding officer of the convention an historic gavel. Mr. Robert Ely is chairman of the gavel committee.

NEW BOOKS

"Resuscitation"—Dr. Chas. A. Lauffer. 4x6½ in., 47 pages, five illustrations. Published by John Wiley & Sons. For sale by The Electric Journal. Price, 50 cents.

This book includes a reprint of a paper on this subject delivered by the author before the Philadelphia Section of the National Electric Light Association. The author, after explaining a number of successful results which have been obtained from employing resuscitation methods on men who were supposedly dead, gives a clear description of the mechanism of respiration, illustrating same by a number of views of the vari-

309.

THE
ELECTRIC JOURNAL

Vol. X SEPTEMBER, 1913 No. 9

Progress in Illumination

The annual convention of the Illuminating Engineering Society to be held in Pittsburgh September 22nd to 26th presents an opportunity to review the recent developments in the field of illumination. A few years ago very little or no attention was given to this subject. Now with the introduction of new lamps and the use of proper reflectors, bowls, globes, etc., the cost of illumination has not only been decreased but a much better quality of illumination is produced. People in general are beginning to realize the importance—in fact, the necessity—of good lighting.

Unshaded lamps are now rarely seen in this country, although abroad the use of the bare lamps is still very common. Not only is the bare lamp annoying but actually injurious. Employers in general, and managers of manufacturing establishments especially, are realizing that better results can be obtained from their workmen under proper lighting conditions, and that the employee, with the same effort, can produce a greater output with less loss in the way of defective material, i. e., with fewer seconds. In the home great improvements have been made, and the use of bare lamps, producing eye-strain, is decreasing rapidly. The use of lamps shielded by bowls, the semi-indirect form of illumination in which a part of the light is reflected to the ceiling and part is transmitted, is without question the most artistic form as well as the most satisfacory method of illumination for both home and office use.

Remarkable progress has been made in street lighting, improving greatly the appearance of our cities. The ornamental post lighting, which has been most popular in the business sections of cities, is also being used largely in the residential sections and in park lighting. A number of interesting examples of this type of lighting are given in the article on "The Lighting of Residence Streets," by Mr. Alan Bright, in this issue of the Journal. Our cities now boast of their improved lighting systems—many of them advertise this feature as one of the attractions of their city.

While much credit must be given to the manufacturers of lamps and also to glassware manufacturers for the development of better illumination, most credit should be given to the Illuminating Engineering Society which has carried on this campaign of education and caused the general public to realize the importance of this subject. HOWARD S. EVANS

Keeping Abreast of the Times

It is a wise old saw that directs us to "know something about everything and everything about something." To the electrical engineer whose daily work has to do with apparatus for power, lighting, railways, etc., the realm of telegraphy, telephony and radio-telegraphy is, for the most part, an unknown land. The articles entitled "Present Practice in Radio-Telegraphy," by Mr. S. M. Kintner, and "The Joint Use of Wires for Telephone and Telegraph Service" by Mr. H. S. Warren, in this issue of the JOURNAL, present instances of the wide range of that "everything" about which every electrical engineer should know something, and it also shows a little of the intracacies of that "something" concerning which we look to the specialist to know everything that is known.

Time was when a single mind could comprehend the entire extent of human knowledge, but that period is long past. Similarly electrical engineering in itself is but a small division of human knowledge, and yet no electrical engineer can hope to cover the entire field. For instance, the electrical engineer, whose specialty is the designing of alternating-current generators, has a view point of the problems of generator design very different from that of the operating engineer whose duty it is to run them; the designer of a power transmission system has likewise little in common with the telephone engineer and his problems of transmission.

Mr. Warren's article will serve to open the eyes of the power engineer to some of the remarkable advances which are being made in one of the allied electrical fields. The degree of precision which is necessary in the manufacture of the repeating coils of the phantom telephone circuit, in order that the delicate high frequency alternations of current—up to 2 000 periods per second—produced by the vibrations of the human voice may be exactly balanced, is as worthy of admiration as the construction of a transformer for a half million volts; while the origination of a scheme for transmitting eleven independent messages simultaneously over two telephone circuits is of the same order of merit as the increasing of the capacity of power transmission lines by the introduction of synchronous condensers.

In comparing apparatus which is used in radio-telegraphy with that for railways, power distribution, etc., we find differences so marked that it is hard to realize that the same agent—electricity—is the actuating principle behind both of them. The differences and not the similarities are what strike the power engineer when he compares the apparatus used in radio-telegraphy with that used in other branches of the art. For instance, when the power engineer designs a transformer, one of his objects is to make the design such that, as nearly as possible, all of the magnetic flux which encloses the primary winding will also enclose the secondary, and that the leakage flux, which encloses one element without also enclosing the other, shall be reduced to a minimum. On the other hand, the radio-telegraph designer makes his transformer so that this leakage flux enclosing one element without enclosing the other is very large compared to that which interlinks both elements, and the result is a piece of apparatus to which the power engineer is almost prepared to deny the right to the use of the name "transformer."

A statement in Mr. Kintner's article which is somewhat startling is that the aerials for radio-telegraphy take currents as high as 150 amperes or thereabouts. It is quite easy to understand how the charging current of a transmission line several hundred miles long can reach a value as high as this, but if the transmission line is reduced in extent so that its capacity is equal only to that of a wireless aerial, it is difficult to understand how it is possible to get so large a current into it. The result is obtained, of course, by increasing the frequencies to a point vastly higher than anything used in power transmission work. It is this statement of the large current absorbed by an aerial which gives one a conception of the tremendously high frequencies that are actually used.

It is well for the electrical engineer occasionally to turn away from his own particular specialty and to learn a little about the methods used in connection with some of the newer developments in other branches of the profession. P. M. Lincoln

THE LIGHTING OF RESIDENCE STREETS

ALAN BRIGHT

A NUMBER of discussions have been published touching upon recent developments in "white way" lighting and the many benefits resulting from ornamental lighting in business sections. That a good street lighting system is an excellent investment not only for the merchants and property owners benefiting directly, but for the entire community is an opinion that is almost universal. The rapid introduction of ornamental lighting in business districts has been accompanied by a quite noticeable increase in property values until there is scarcely a city or town that does not have or is not considering an installation.

The question is often asked, "If ornamental lighting in business sections reflects credit upon a city, why is it that ornamental lighting is not introduced in residence districts?" The principal reason why residence streets have not been lighted with ornamental units is that the expense connected with the improvement would not warrant the installation. In business sections the advertising value of ornamental lighting, in most cases, justifies large appropriations. However, improved methods in manufacture and simpler designs have made it possible to adopt decorative lighting in outlying districts. In many places real estate dealers have realized the commercial value of ornamental lighting in residence districts and with a moderate expenditure have rendered their tracts salable.

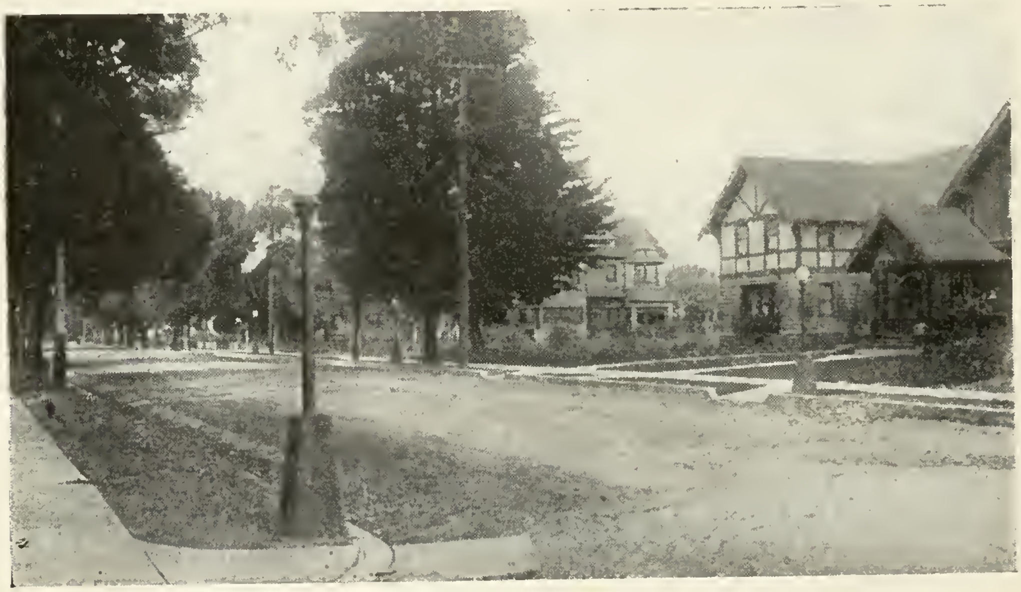

FIG. 1—INEXPENSIVE METHOD OF SUPPORTING LAMPS AS USED IN ALAMEDA, CALIF.

The lighting equipment that has been common in residence districts consists of enclosed carbon arc lamps suspended above the center of the street, usually at street intersections. With this arrangement the lamps are effective during the winter months, but on most streets the foliage prevents the light from reaching the sidewalks and a portion of the street itself during the summer. The presence of trees that arch over the street has made it necessary, in many cases, to lower the mounting height of the arc lamps. When this is done, it is difficult for automobile drivers to distinguish objects beyond the region of brightness immediately beneath the arc and accidents are liable to result.

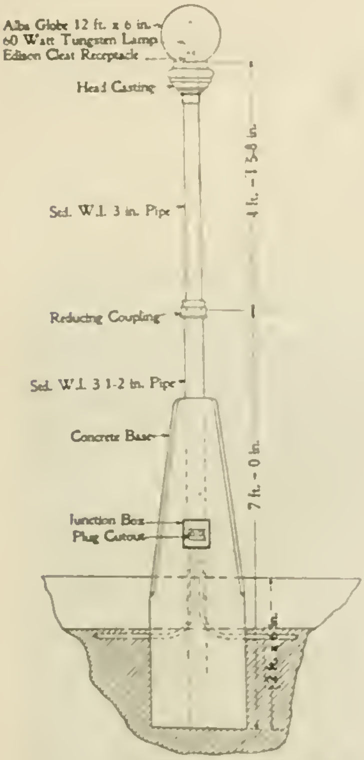

FIG. 2—DETAILS OF LAMP POST, ALAMEDA, CALIF.

It would be absurd to expect residence streets to be lighted with the same equipment and with the same light intensities that are common in business sections. Lighting on residence streets has no "trade drawing" function, but serves rather to make the roadway safe for pedestrians and for traffic. However, the fact that lower light intensities suffice in residence districts is no reason why modern equipment and modern construction should not prevail in such places. It is not at all unusual to see streets that are well paved and have up-to-date sidewalks and curbing, but are marred

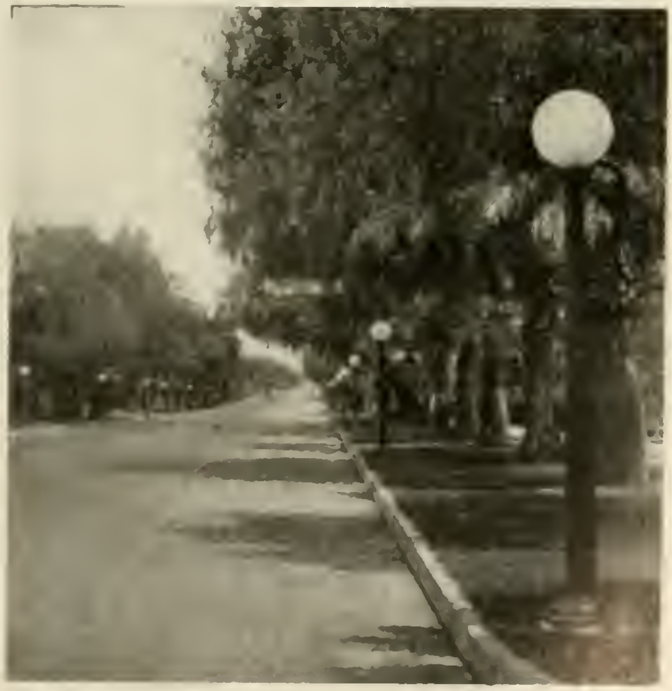

FIG. 3—ORANGE GROVE AVENUE, PASADENA, CALIF.

by heavily scarred wooden poles and a network of wires. Where these poles and overhead construction have been replaced by modern equipment the resulting benefits seem to warrant the expenditure.

THE ALAMEDA SYSTEM

The system in Alameda, California, is an excellent example of what may be accomplished by an enterprising city administration. The abundant foliage on the Alameda streets made the light from the old arc lighting units very ineffective. To offset this disadvantage a post of the type shown in Figs. 1 and 2, of the city's own design, was selected. The post consists of 3½ and 3 inch iron pipe with a concrete base and cast iron top. The total height to the top of the globe is 9 feet 7⅝ inches. The staggered arrangement of posts is used, there being 150 feet between posts on one side of the street.

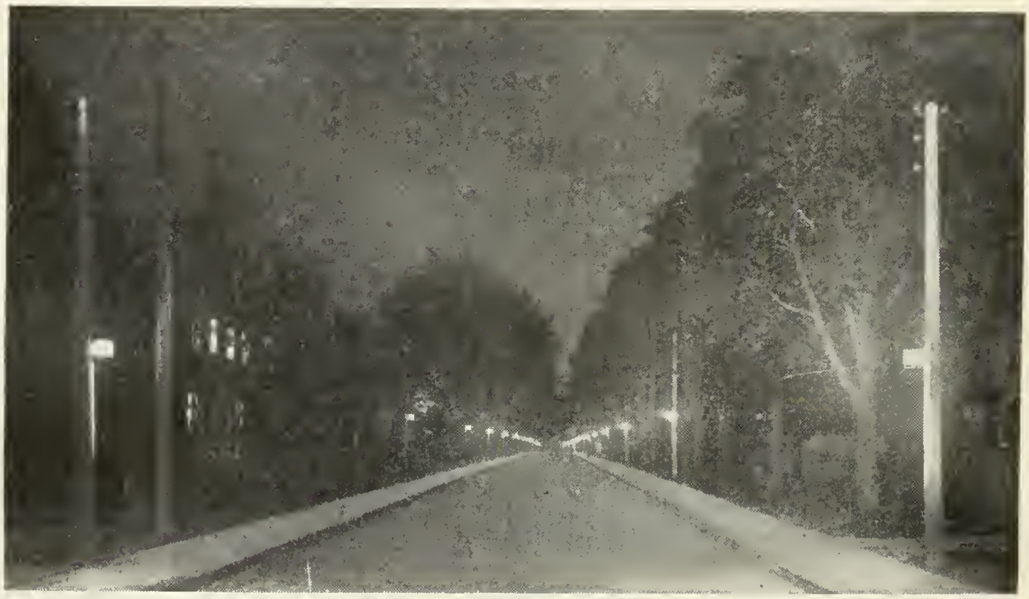

FIG. 4—NIGHT VIEW, TORONTO, ONTARIO,
Showing bracket lighting on Charles street.

Each post supports a 60 watt tungsten filament lamp enclosed in a 12-inch Alba ball globe. All exposed metal and cement surfaces are painted green. About 4 000 of these single light standards have been installed in the city, covering every street, including all of the residence sections. The cost of installation is about 21 cents per foot front and is assessed against the property owners. The posts cost $11.50 each installed and, while not particularly ornamental, have stability, resulting in long life for the tungsten lamps, and are something that most communities can afford. All of the arc lamps in the city have been removed and the street lighting consists entirely of tungsten lamps. The tungsten lamps are operated in parallel on 110 volt lines supplied from transformers connected to 2 300 volt street lighting circuits. The city owns and operates the electric light plant. The maintenance of the street lighting system is taken care of by the light plant and the electric current required is charged for by the city of Alameda at the rate of 2¼ cents per kilowatt-hour. Some of the lights have been in operation for more than a year, and the system is highly satisfactory, due to its superior distribution of light over the arc lighting system and on account of the low cost of installing.

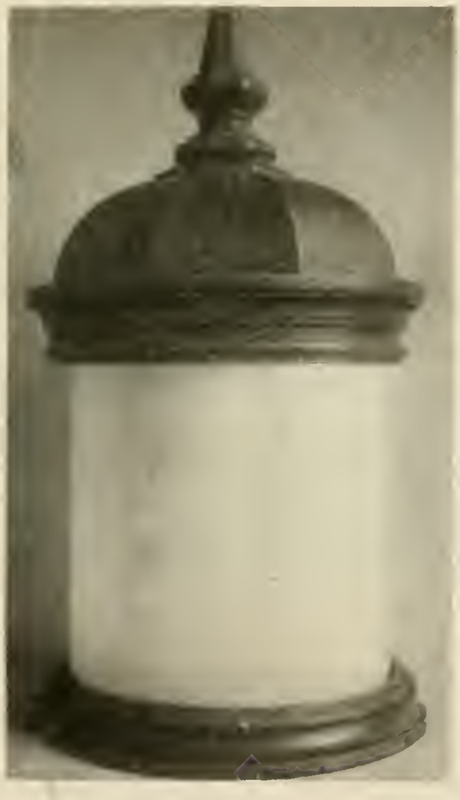

FIG. 5 CAST IRON BRACKET USED IN TORONTO

ORANGE GROVE AVENUE, PASADENA

In contrast with the Alameda installation is the installation on Orange Grove Avenue, Pasadena, California, illustrated in Fig. 3. A distance of 8 000 feet is lighted with single light posts made of solid bronze costing $90 each. The height to the top of the globe is 10 feet 2 inches. The standards are set one foot inside the curb, and rest on a base of concrete two feet square and 20 inches deep. There are 170 posts, each supporting a 100 watt lamp enclosed in an 18-inch Alba diffusing ball globe. The total installation cost is $30 000. This cost averages about $176 per post, which is far above what most places can afford. This cost does not include the cost of conduit, which amounted to about 32 cents per foot. This installation is mentioned to show the expense that is sometimes put into installations privately by groups of residents.

TORONTO, ONTARIO

The most satisfactory method of installing ornamental lighting is to place all wires underground. However, in Toronto the post design and the method of suspending the wires has been so improved that the system of lighting in the residence section of that city is looked upon as being quite ornamental. A concrete pole has been designed and manufactured by the municipality at a very low cost. There are no cross-arms of the ordinary type, the wires being suspended vertically. The street lighting wires are on the street side of the pole, and the residence lines are on the opposite side. The overhead and upper part of the concrete poles are almost completely hidden on the streets where trees are abundant. A view of this installation, taken on Charles street, is shown in Fig. 4. The lamp bracket itself, shown in Fig. 5, is of cast iron and weighs approximately 26 pounds. They are mounted vertically on the street side of the pole, nine feet two inches above the sidewalk and are placed 90 feet apart on both sides of the streets. Each bracket contains a 100 watt lamp enclosed in an eight-inch cylinder of diffusing glass. The system was installed and is maintained by the municipality.

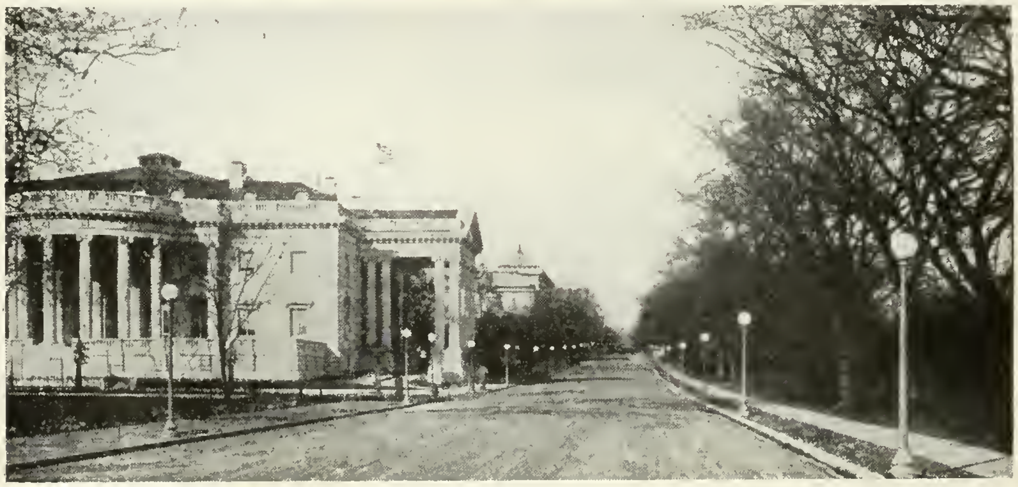

FIG. 6—SEVENTEENTH STREET, NEAR PENNSYLVANIA AVENUE, WASHINGTON, D. C.

An installation similar in appearance, but much less costly, is illustrated in Fig. 6. The view shows Seventeenth street, Washington, D. C., between Pennsylvania avenue and B street. The posts are made of cast iron and are 12 feet high. Tungsten lamps of 100 candle-power are enclosed in 16-inch diffusing ball globes. This system of lighting has been adopted throughout the city.

Ornamental lighting, whether applying to residence streets or business thoroughfares, is worthy of consideration in all cities. It reflects credit upon the city and pleases residents and visitors alike.

PRESENT PRACTICE IN RADIO-TELEGRAPHY

S. M. KINTNER
General Manager
National Electric Signaling Company

TO those who have not been in close touch with its development, radio- (wireless) telegraphy has had a checkered career. In its early days, and in fact up to within a very recent time, it was used as a means of "gold bricking" and the success with which this was done can be judged by the testimony that can be secured from thousands of small investors, scattered throughout this entire country, who were tempted to part with their savings by the alluring advertisements. Radio-telegraphy as an art, was not to blame for this, although it has suffered very much from the effects, and these ill effects have greatly hindered its development. It has reached a place today, however, where its worth has been definitely proven and the installations are being made now, in most part at least, only after careful consideration, both from the engineering and financial points of view.

This article was written with the intention of placing before the readers of this journal, a brief statement of radio-telegraphy as it is practiced at the present time. It is anticipated that most of the readers are not especially familiar with this phase of the general subject of electrical engineering and consequently it becomes necessary to start with the fundamentals.

Radio-telegraphy differs from ordinary or line telegraphy, principally in that its signals are sent out or radiated broadcast, by means of electromagnetic waves; whereas, line telegraphy has its effects guided by wires. The methods employed by the operator in manipulating his sending key are the same in both instances; so also, in a more general sense, do the receiving operators receive their messages in the same way in the two systems, i. e., by listening to the production of sounds of short or long duration and with different time spacing between them, according to the Morse code. With the idea then, that the general practice of the two systems is the same, we can turn our attention to the points of difference.

The energy involved in sending out the signals in radio-telegraphy is put into the form of electro-magnetic waves which are radiated intermittently in conformity with the wish of the operator as he manipulates the key according to the Morse code. An electro-magnetic wave is a strain or "splash" in the ether which travels out in all directions from its source. It is similar to a light wave which travels out from a source of light going in all directions. A free electro-magnetic or Hertz wave is, in fact, so far as our knowledge goes, exactly the same thing as a light wave, excepting as to size. The Hertz wave is very much longer than the light wave. The light wave for yellow light is approximately 1/50 000 of an inch long, whereas, the ordinary electro-magnetic waves used in radio-telegraphy are approximately 600 meters long. There is another difference between the light wave and the type of electro-magnetic wave used in radio-telegraphy, and that is, whereas, the light wave is free and radiates out in straight lines, the electro-magnetic wave is, according to our best theories, a bound wave. It is supposed to slide over the surface of the earth in a manner somewhat similar to a water wave sliding over the surface of the water. This sliding theory answers best all the known phenomena and particularly the rate of diminution of strength of the effects with increase in distance and the fact that the earth's curvature has practically no effect.

An electro-magnetic wave is believed to be a strain or quiver in the ether which travels out from the source of origin at the enormous speed of 300 000 kilometers per second. This strain in the ether is produced in radio-telegraphy by an alternating current passing up and down a vertical wire, which is connected to earth at one end and which has an area made of a net work of wires at the top. The higher the frequency of this alternating current the more effectively will it radiate its energy by the development of electro-magnetic waves. Thus, in practice only comparatively high frequencies are employed. The lowest frequency in regular commercial use at present is approximately 45 000 cycles per second. This is, of course, far beyond the ordinary frequencies employed in power transmission and house lighting, which latter are so low as to be of no value for radiation. The most common radio-wave frequency is about 500 000 cycles per second and constitutes the upper limit of frequencies reserved by the United States Government.

The lower frequency thus reserved is 187 500 cycles per second. The above range of frequencies embraces the most desirable ones for use on ships. This is true principally owing to the conditions governing the amount of aerial radiating wire that can be carried to good advantage.

In radio-telegraphy it is common practice to speak of wave lengths instead of frequency in cycles per second, the wave length being expressed in meters. The wave length is readily determined by dividing the speed of travel, i. e., 300 000 kilometers, by the frequency. Thus, the Government wave length reservation is from 600 meters (500 000 cycles per second) to 1 600 meters (187 500 cycles per second). These electro-magnetic waves have the property of collapsing when striking against a conductor and the result of this collapse is an electric current. Thus, it is practice to make use of a similar aerial at the receiving station on which the waves may collapse and develop electric currents. Owing to the alternating character of the waves, the currents produced are alternating, or more properly oscillating, as each succeeding wave of a group is smaller in amplitude than its predecessor although of the same wave length. A radio-telegraphic receiving station consists then, fundamentally, of an aerial on which the electromagnetic waves may strike and striking may collapse and produce oscillating currents, and a current indicating device and accessories for assisting these currents to effectually transfer their energy to the indicating mechanism.

The probable fact that the rarefied gas of the earth's atmosphere is, at heights of about 50 miles, a good conductor, and that conductors act like mirrors in reflecting electro-magnetic radiations, is believed to account for the limited rate of decrease in energy found in waves at great distances from the exciting source. The effect that sunlight, and even moon-light in some instances, has upon the distance of transmission, is very marked, much greater distances being covered at night than are possible in day-light. This effect is very noticeable when short waves are employed but is not so pronounced with the longer ones. As a result of this daylight absorption, as it is generally called, it is best to use long waves for long distance sending. Fortunately this works out to advantage as the long waves are produced most readily and efficiently on the large aerials or antenna which are, of course, most suitable for the long distance signaling. There is a great difference in the ease of transmission over different surfaces. Salt water is the best, while transmission over rocky land, with buildings, etc., is very poor. Thus it is impossible to select a proper power and design of sending station without knowledge of its working conditions.

The wave length of the waves radiated from any antenna can be made any desired value by a change in the inductance and capacity, but there is a particular wave length for each antenna at which the best and most economical radiation will be secured. For a limited range on either side of this best condition, effective radiation can be secured but beyond it the effects are poor, such radiation as is secured being produced very inefficiently.

SENDING STATIONS

The modern sending stations are of two distinct types:—

a—The spark or damped wave system;

b—The continuous or undamped wave system.

Both of these will be described briefly as they are of such importance at this time, as to warrant consideration of them both.

The spark system is the older one of the two. It employs a spark discharge of energy stored in condensers as a means of setting up high frequency currents. These high frequency currents are employed to excite the antenna and in this way produce radiation. It will be evident that the amplitude of each oscillation of the currents set up by condensers discharging will be less than that of its predecessor. This reduction of amplitude is spoken of as damping and is caused by a reduction of the energy involved in the successive oscillations. This loss of energy is brought about in two ways:—

1—In over-coming the resistance of the circuit, thus producing heat;

2—By radiation of energy, by the detached ether strains which go out as electro-magnetic waves.

The antenna resistance then, as commonly used, is a term which includes both the ohmic factor and the radiant factor—the relative proportions are generally unknown. The total activity of the antenna is determined than by I^2R, where I is the antenna current as measured by a hot-wire ammeter, or similar instrument, placed directly in the antenna, and *R* is the total antenna resistance. The antenna resistance is generally determined by some method of substitution of additional known resistance and noting the change in the damping of the waves.

The connections usually employed in a spark system sending station are shown diagramatically in Fig. 1. A consideration of this diagram will make it evident that the purpose of the apparatus is to change a low frequency alternating current to a high frequency current. This high frequency current, as previously mentioned, by charging the aerial, sets up strains or quivers in the ether, which are detached and travel outward from the antenna as a center.

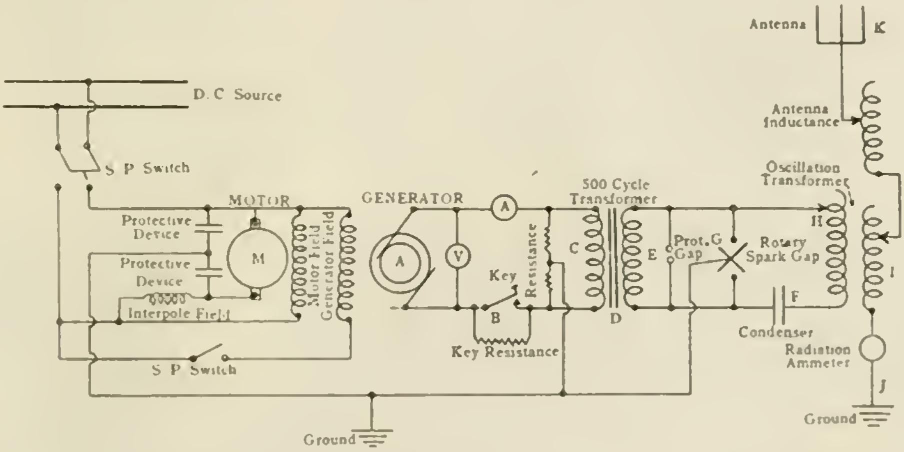

FIG. 1—SCHEMATIC CONNECTIONS OF A TYPICAL SENDING STATION

A—Is a single-phase alternating current generator. In modern stations a frequency of 500 cycles is most generally used; *B*—Is a sending key, used by the operator in making dashes and dots by closing the circuit for longer or shorter periods; *C*—Is the primary of an iron core transformer; *D*—Is an iron core, generally of the open magnetic circuit type; *E*—Is the secondary of a transformer, giving for small and medium sized stations about 12000 volts; *F*—Is a battery of condensers, in which the energy to be converted into oscillations of high frequency, is stored; *G*—Is a gap discharger for releasing the stored energy of the condensers periodically and permitting it to oscillate in the local circuit *F, G, H*; *H*—Is the primary of the oscillation transformer, a Telsa type air core transformer; *I*—Is the secondary of the oscillation transformer; *J*—Is the antenna earth connection; *K*—Is the overhead wire for radiating the wave energy.

A good idea of the appearance of the elements of a 100 kilowatt set may be obtained from Fig. 2. This particular set is the one installed at Arlington, Va., by the United States Navy Department. By comparing Figs. 1 and 2 it will be found possible to trace the wiring connections. The compressed air condensers shown are built of metal discs assembled in two groups insulated from each other and in which the condenser dielectric is air under a pressure of about 300 pounds per square inch.

This air compression increases very much the dielectric strength of the air and allows rather close spacing of the condenser plates. Owing to the dielectric losses that exist when solid dielectrics are employed with high frequency currents, it is essential to use, in high powered sets, condensers employing air dielectric.

The second type of sending station, i. e., the type employing continuous or undamped waves, consists fundamentally in the placing of a generator of alternating current, of the frequency of the waves radiated, directly in the antenna. To Fessenden belongs the credit of having been the discoverer of this

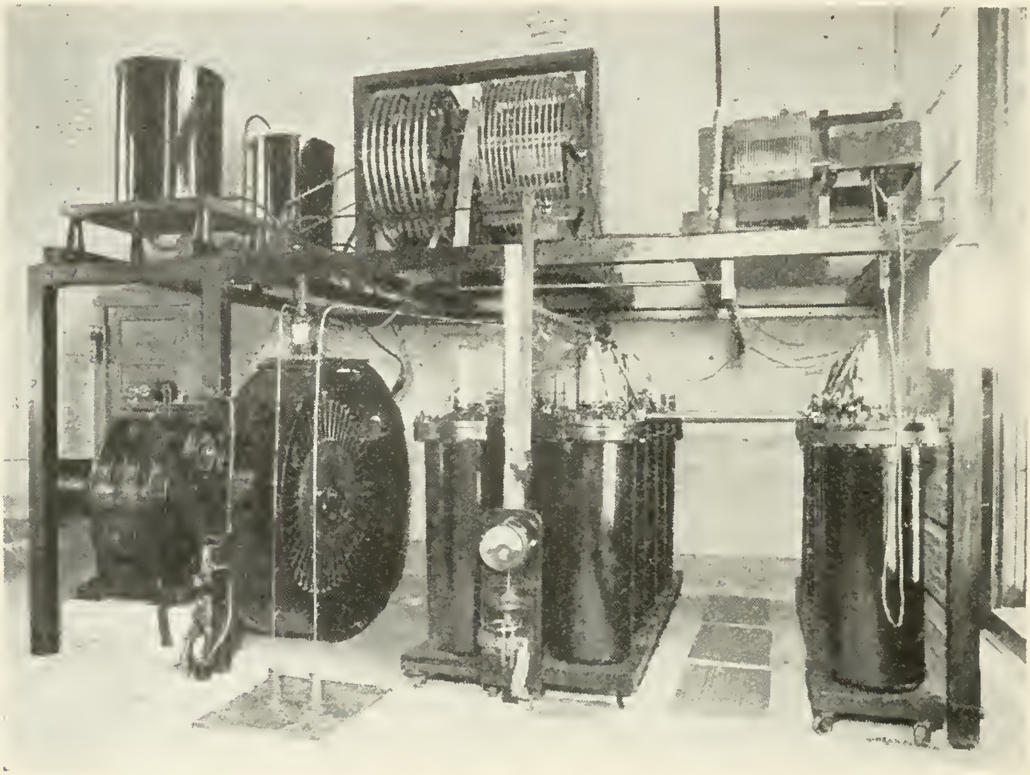

FIG. 2—SENDING APPARATUS IN ARLINGTON STATION

The generator is shown in the lower left hand sid eof the illustration. The transformer is below the floor; the two leads coming up through floor terminals are the high tension wires from it. The several tanks with heavy covers are compressed air condensers for storing energy from the transformer and then suddenly discharging it through the rotary discharger to secure the high frequency oscillating current. The two tanks at top (left) are cooling tanks from which water is circulated through the stationary electrodes of the gap The two coils (top center) are the primary and secondary respectively of the oscillation transformer. The coil (top right) is an inductance directly in the antenna. The heavy lead from the inductance coil goes out through a window to the aerial. The ammeter shown on the post is on the ground end of the antenna, and indicates the current charging up and down the aerial leads. This amounts to about 150 amperes when sending at full power.

system. The effect of this type of generation is to produce alternating current directly in the antenna and hence the radiation of electro-magnetic waves, in which the amplitude is the same for successive waves, and in which the action is continuous as contrasted to the intermittent action in the case of the spark system. In the spark system a group of waves results from each spark. In each of these groups of damped waves there will be, under favorable conditions, 15 or 20 waves sent out. A simple calculation will show that even under very favorable conditions with a spark frequency of 1000 per second with a fairly persistent radiation having 20 waves per group and a wave length of 600 meters, that the antenna will be actively engaged in radiating only about 1/20 part of the time and the rest of the time it is inactive. Now, it is a well recognized principle that, if good results are to be secured from resonant action, it is necessary that the exciting source be very persistent. Think back to your school days for an analogous condition and recall how you set the schoolhouse floor in vibration by a rapid movement of the legs up and down pivoted on the balls of the feet. You will probably remember that persistent and exact timing of the rate of movement were the prime essentials. Think of how much vibration you could have secured if you had remained quiet 19/20 of the time. These same conditions of resonance hold in the electrical circuits.

The real superiority of the undamped waves, radiated according to the second method, lies in the improved resonance effects possible. These improved resonance effects permit the use of receivers that are more sensitive and which respond to a more limited range of wave lengths and hence are much less liable to interferance from other stations and from atmospheric conditions, lightning flashes in the distance, etc. Owing to the sharpness of tuning possible with this type of radiation, it is possible to send the signals by simply changing slightly the wave length of the waves radiated, according to the Morse code, without an actual interruption of the source of power. Thus, the station can radiate continuously but with the wave lengths changed to produce the dots and dashes. These are received as sounds when radiating the proper wave and silence when the other wave is going. Should the receiving operator make a mistake and tune for the wrong wave he would, of course, have his code reversed, getting spaces for dots and dashes and dots and dashes where spaces were intended. This is not apt to cause any particular difficulty with a good operator as he would recognize the trouble and correct it.

RECEIVING STATIONS

The type of receiving station has been determined very largely by the detector, the other parts of the station being made to best suit the particular type employed. Detectors can be divided into two general classes:—

a—Those operating as triggers or relays, wherein the energy received from the sending station is used to trip a trigger and allow a local supply of energy to operate some indicator.

b—Those operating so as to give an indication directly by means of the received energy, thus getting proportional responses.

In the earliest radio-telegraphic work, that of Popoff in Russia, of Lodge in England, and later, of Marconi in Italy, detectors of the first class were employed. These were named "coherers" by Lodge and were generally supposed, at that time, to be the most sensitive electrical device ever invented by man. They were popularly spoken of as the "electric eye" and were looked upon as the one piece of apparatus, of all employed, whose perfection had made "wireless" possible. Coherers have now gone out of use, owing to the superior qualities of the other types of detectors. There is, in fact, only one type of relay, or trigger operating detector that is enjoying any very extended use at this time and that is Marconi's magnetic hysteresis type. It depends upon a principle, first announced by Prof. Rutherford, that the hysteresis in a small mass of steel, can be shaken out by currents set up by Hertzian waves. Marconi has used this quite successfully, though it is now giving way to other forms of detectors which give proportional responses.

Fessenden's liquid barretter was the first commercial form of detector, giving proportional response, that met with very general favor. It was brought out in 1902, and produced such amazing results that it caused a complete change in the development of the art. The liquid barretter consists of a small piece of Wollaston wire dipping into dilute nitric acid. The Wollaston wire employed is usually three or four mils in diameter with a platinum core of only about 1/10 of a mil in diameter. The small core extends into the solution only three or four thousandths of an inch and the effective part consists of the liquid in the immediate region involved in the contact. When operating in best condition, a small current from a battery is passing through the detector. This small current serves only as a means of keeping it in its most sensitive condition. The received energy which, upon collection by the aerial develops oscillating currents, is passed through the detector, either directly or in a derived circuit by means of a transformer, and the detector acts as a rectifier and changes the oscillating current to a undirectional, though intermittent, current. This unidirectional current can then be used directly in a telephone receiver. One group of these rectified currents produces but one movement of the telephone diaphragm, the individual waves of the group being of such extreme frequency, in so far as mechanical movement is concerned, as to make it impossible of response to them. Even assuming the telephone diaphagm could respond to the individual waves, instead of to groups only, it would produce no useful result as the frequency is far too great for the human ear to follow and accordingly no sensation of sound would result. In practice the spark frequency is always some place between 60 and 1 000 sparks per second so that the telephone gets a series of impulses. If now the method of producing the spark frequency is very carefully adjusted so that the spacing of the sparks is very exact, a musical note will be heard in the telephone, the pitch, of course, being dependent on the spark frequency. This type of detector is so rapid in its action and so accurate in its regularity of response that operators can readily distinguish one sending station from another by little irregularities in their spark tones which are more or less characteristic. Expert operators can in fact actually distinguish the sending of one operator from another. The results then, with this type of detector, are more nearly like hearing what is going on at the sending station, while the coherer type gives only a release of the local energy supply and consequently all sending stations sound alike.

The success of the liquid barretter was so great that other detectors, working on the same general principle of rectification, soon followed. Thus rectifiers were produced for each of the three conditions of matter, i. e., liquid, gaseous and solid. The first of the three is most readily reproduced in a degree of sensitiveness desired and it has therefore come to be recognized as a standard of sensitiveness. The crystals are generally used with a battery in the same manner as the liquid barretter, though some of them are so sensitive as not to require a battery.

A typical wiring diagram for a receiving station to operate with rectifying detectors, with a spark system sending station, is shown in Fig 3. The spark-gap shown connected between the antenna and ground is really a lightning arrester. The resistances, shown shunted around the condenser in the antenna and the condenser in the closed oscillating circuit, are for protective purposes and serve as a leak for high voltage charges. They are generally made of graphite rods and have a very high ohmic resistance. The detectors shown are of two types, liquid barretters and crystals, two of the former and one of the latter being mounted in the particular installation represented in the sketch. These detectors are provided with a condenser which can be shunted around them as a protection against too strong currents, such as are apt to be picked up during the sending on a nearby set. This condenser is cut out during the receiving operations. The test buzzer and its circuits are for the purpose of determining the condition of sensitiveness of the de-

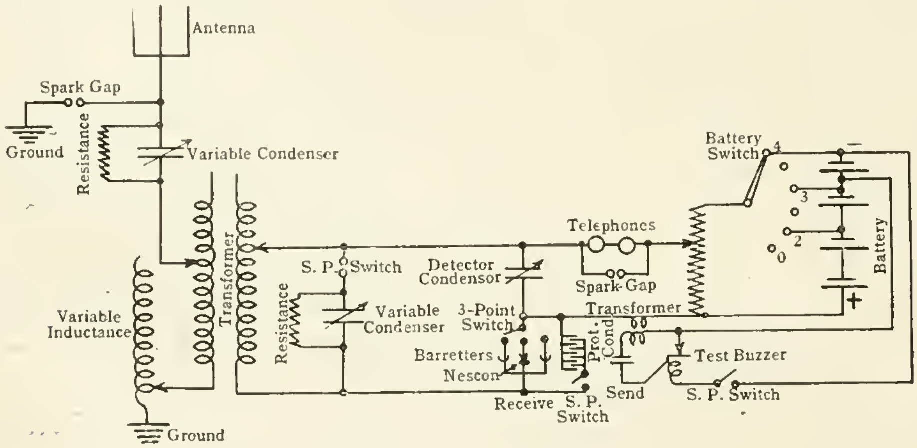

FIG. 3—SCHEMATIC CONNECTIONS OF A TYPICAL RECEIVING STATION

tectors. For instance, there are times when a message is suddenly interrupted and the receiving operator must know whether the fault is at his station, or the sending station. If he hears signals when he puts on the buzzer he knows at once that his detectors are all right, while the absence of signals from his buzzer indicates that his detectors are at fault and he switches to another detector, or corrects the fault on the one in use. As a rule but one or two cells of battery are required to give the proper voltage from the potentiometer for operating the detectors. The larger number are used principally in forming a new point, the larger current carrying away the excess silver from the Wollaston wire contact and leaving the small platinum point exposed.

In the operating of a receiving set of this type the antenna circuit is first tuned to the frequency of the desired signals by adjustment of inductance and capacity. The secondary of the transformer is then moved away from the primary and it is tuned by varying the inductance and capacity till the greatest strength of signals is secured. It is generally necessary to readjust each of these tunings as a change in any one upsets the adjustment of others. The separation of the two coils of the transformer is for the purpose of allowing each circuit to oscillate more nearly at its own natural rate without any inductive interference from the other. It also limits the transfer of energy from the primary to the secondary, particularly, if that frequency be one for which the secondary circuit is not resonant, and thus makes it possible to secure great selectivity in the secondary circuit. The arrows on the condensers indicate that they are adjustable. The arrows on the ends of the leads attached to the inductance also indicate variability for adjustment.

Receivers of these types are employed with the spark system sending sets only, as the sound the operator hears corresponds quite closely to the sound of the spark one hears when at the sending station. With the radiator sending out waves continuously no sound would be heard by an operator using a set like those described, as the wave frequency is far above the limit of audibility. This type of receiver can be used with the continuous type radiator provided the radiation is chopped up into groups by some form of interrupter, but this is really changing the radiation till it approaches at least, the spark type system.

There are two types of receivers for continuous or undamped radiators proper. The first of these is based upon the chopping up of the energy at the receiving station so as to get a sound. This is generally accomplished by some form of contact maker which closes a circuit around part of a resonant circuit. This breaking in on the resonant circuit, destroys the condition of resonance and causes it to give up a large part of its energy to the condenser that is suddenly connected in on it. The charge on the condenser is later allowed to pass through telephones and thus produce the signals. This charging and discharging of the condenser takes place at a rather rapid rate, several hundred times per second and gives a rather "hissy" sound.

The heterodyne receiver works upon the principle of producing an audible frequency by interference beats, caused by superposing, on the alternating currents produced in the receiving antenna by the sending station, of an alternating current, produced locally, of a slightly different frequency. These interference beats give a pure musical tone which can be adjusted in pitch by changing the frequency of the local circuit. It is possible also to amplify the strength of signals by increasing the strength of the local current and thus produce a marked improvement in the signals. This amplification, combined with the fine tone of the signals, makes this the best method that has yet been developed for receiving signals.

The greatest trouble, experienced at receiving stations, as might naturally be expected, is that due to interference. This interference is caused by:—

a—Atmospheric disturbances; b—Signals from other stations. The atmospheric troubles are very severe in the tropics during certain seasons and cause a continuous rumble in the telephones which is very annoying and makes the reading of weak signals impossible. This sound resembles that made in the frying of grease on a hot stove or like a series of small explosions. There are two methods of overcoming this difficulty, these are, however, only partially successful. The first method relies upon accurate tuning and reduces the disturbances very materially, but under heavy atmospheric conditions this is not always sufficient to make it possible to read the desired messages. The second method consists of adding to the first the musical tone qualities of the desired signals so that they can be physiologically separated from the disturbances. The tone most effective is one produced by a frequency of 1000 per second and, in the spark system, this is secured by producing 1000 very regularly spaced sparks per second. This same tone can be secured with the heterodyne by adjusting the local frequency to an amount that gives 1000 beats per second. The heterodyne gives musical tones when receiving undamped waves but not when operating with the spark system giving damped waves.

The second serious difficulty encountered in operating receiving stations is from the interference of other nearby sending stations. This is overcome by tuning, provided the stations that are sending have their apparatus properly adjusted so as to send out a very pure type of radiation. If the radiation be of waves of excessive damping, or of two or three wave lengths superposed, they cannot, if sufficiently near or powerful, be tuned out. An act of Congress, passed a year ago, prescribes certain limits of purity of radiation beyond which a station must not go. This has had a very beneficial effect in improving the character of radiation and thus made tuning a real remedy for most of this type of interference when the stations are working on different wave lengths. Unfortunately the law specifies certain wave lengths that must be employed on ships and stations working with them, and this increases the interference around busy harbors, such as New York. The heterodyne receiver when working with undamped waves, is the one that gives the most reliable results, and is most free from interference of any in use at this time.

As to the sensitiveness of the receivers in general, the following taken from the Presidential adress of Mr. William Duddell, F.R.S., before the Institution of Electrical Engineers in November, 1912, is of interest:—

"The radiation in wireless telegraphy is similar to light; therefore, it is of interest to compare the human receiver of this radiation, namely, 'the eye,' with the receiver of a wireless station. According to some recent experiments by Messrs. Patterson and Dudding, a light of 1/10 of a candle at a distance of one kilometer is near the limit of visibility. Assuming the square law, this corresponds to a candle-power of 2 560 at 100 miles. With our present incandescent lamps this would require 2.5 kilowatts. In wireless, to cover the same distance, it is usual to install what is nominally a 1.5 kilowatt station.

"Taking, however, Drysdale's figures for the rate of radiation of energy in the visible spectrum (about 0.1 watt per candle-power) our source of light is radiating energy at the rate of about 250 watts. Very accurate figures for the rate of radiation for a wireless antenna are not available, but assuming an overall efficiency of 20 percent; the radiation of the wireless antenna is 300 watts. It would seem, therefore, that there is a remarkable similarity between the sensibility of the eye to radiation of the short wave-length which constitutes light, and the sensibility of the wireless receiving apparatus for the long wave-length radiation used in telegraphy.

"According to Lord Rayleigh's experiments, if a tuning fork is producing sound at the rate of 42 ergs per second it will just be audible at a distance of 30 yards. This corresponds to a source of sound giving 0.0056 watt being audible at one km., or assuming no absorption or bending of the sound waves, 143 watts at 100 miles. We, therefore, have the curious result that if it were possible to radiate energy at a given rate, either as sound waves or as light waves or as long Hertzian waves, we should be able to detect them at approximately the same distance by means of our ear or our eye or the receiving apparatus of a wireless station."

Mr. Duddell's comparison while, of course, intended to be only quite rough, does not give the radio-apparatus quite enough credit for sensitiveness. The receiving apparatus with which he is apparently familiar is not nearly as sensitive as the heterodyne, which is probably four or five times, at least, as sensitive as the older types. Furthermore, the use of higher aerials at both sending and receiving stations would increase very materially the working range even with the same amount of energy radiated. Whereas Mr. Duddell selects 1.5 kilowatts as the proper size of set for 100 miles, it is nothing uncommon for sets of that size to work 300 miles in daylight. There are numerous instances of two kilowatt sets, a somewhat standard size in this country, working 600 miles daylight and 1200 miles or more at night. These exceptions are made to Mr. Duddell's very interesting comparisons only for the purpose of showing that the radio-apparatus is more sensitive than the human eye, and also to indicate the various causes that may influence the apparent sensitiveness.

The sensitiveness of the average human ear to tones of a frequency of approximately 1000 per second, as determined by a telephone with alternating current, is about eight micro-microwatts. That such extreme sensitiveness is required is perfectly evident when one thinks of a given amount of energy thrown off from a radiating antenna as a strain, or quiver, in the ether like an immense water wave which, as it goes from the source spreads out and thins down the energy per unit of length along the crest of the wave directly with the distance; and which also spreads upwards to the probable limit of a conductive envelope that is formed by the rarefied atmosphere about the earth; and again when one allows for the loss of energy all around the wave caused by a drawing out of certain amounts as the wave rushes past conductors, such as trees, buildings, etc., and still further when one remembers that the only part of the energy that is useful in producing the desired signal in that whole big wave circle is a part represented by an area probably equivalent to about the square of the height of the antenna.

Experience has shown that the distance of transmission varies directly with the product of the heights of antenna, at sending and receiving stations; the rate of decrease in energy with distance being between the first and second powers of the distance. What is desired in an antenna is a large capacity area at a great height. The capacity should be large, if large power is to be radiated, and the voltages kept down to reasonable values. The capacity of receiving antenna is preferably less than that of the sending. This is for the reason that there is then no trouble from high voltages and it gives an antenna which has a larger proportion of inductance and thus tunes better and picks up fewer strong waves of frequencies not desired. The capacity area is secured by stringing stranded wire between insulated horizontal supports. These wire-s are generally about five feet or more apart, no appreciable advantage being secured by stringing extra wires in between.

The earth connections are best made by contact with a surface spread over a considerable area. The ground connection at the Arlington station is made by forming a large net of copper ribbon spread out over several acres and the antenna lead conected to it. An effective earth can also be made by a large net work of wires supported a few feet above the earth's surface. In this arrangement the net work becomes one plate of a condenser of which the earth is the other. This arrangement gives excellent results in certain locations where earth connections of the usual kind are difficult to secure.

While the operations of radio-telegraphy have been confined largely to ship work, where it has no competition, there can be no doubt that, with the increased reliability of service which is gradually being achieved, it will find other fields of operation, particularly in competition with cables, where it will be more economical than existing methods.

The speed at which messages may be sent depends so much upon the operating conditions that only a very general statement can be made. Under favorable conditions the limit is that of the individual operator and may reach 50 words per minute, or more, with extra good men. Under conditions of interference it may drop to 15 or 20 words per minute, while with weak signals and interference it may even go still lower, owing to repetitions, etc.

There are a number of methods of sending more than one message from the same antenna at the same time. Also methods of sending and receiving on the same antenna simultaneously, but none of these have been put in sufficiently good form to cause them to be used commercially. Machine sending and receiving has been tried by a number of different experimenters but as yet with only indifferent success. It is perfectly feasible to do this under favorable conditions but interference causes great difficulty with this method, more than with ordinary operation with the individual listening and selecting, by concentrating his attention, the desired from the stray-interfering signals. While a great advance has been made in the development of this art during the past fifteen years, much remains to be done and it is quite likely that methods which are standard today will be obsolete within five years.

The above is intended as a brief statement of present-day practice.

THE JOINT USE OF WIRES FOR TELEPHONE AND TELEGRAPH SERVICE

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IT IS a fortunate circumstance that telephone currents and the commonly employed kind of telegraph currents are of such character and relation that under favorable conditions both can be transmitted simultaneously over a circuit without either one interfering with the other. For several years it has been commercially possible for certain classes of telephone circuits to be utilized also for telegraphic communication without interfering with their regular use for telephone purposes. The telegraph service thus afforded is of very high grade; in fact, simultaneous telephone and telegraph operation is of itself a guarantee that the lines will be kept in first-class condition.

TELEPHONE CURRENTS

The wave forms of telephonic voice currents are exceedingly diversified and complex. Every sound in a telephone transmitter produces its own peculiar train of electric waves which distinguishes it from every other sound. Even the same word or syllable spoken by different persons produces telephone waves of different characteristics whereby the voices of different individuals may be recognized. An efficient telephone circuit must transmit telephone waves at approximately the same velocity and with approximately the same attenuation, otherwise the sounds will be distorted and, as heard at the receiving end of the line, will not correspond accurately to the waves sent out by the transmitter. The normal range of the human voice for pure tones is approximately from 80 to 800 periods per second. The fundamental tones employed in talking fall within much narrower limits. In order, however, to take care of overtones, a telephone circuit should transmit waves up to at least 2000 periods per second, otherwise quality of transmission will be impaired. It is also desirable to be able to transmit the lower periodicities within the compass of the voice.

TELEGRAPH CURRENTS

While several alternating-current telegraph systems have been devised, direct current is ordinarily used in telegraphy in this country. The current is caused to flow for a longer or shorter time to register a dash or dot respectively, the intervals between successive dashes and dots representing periods when the flow of current is interrupted or reversed. The actual length of time during which the current flows in one direction may vary from approximately one-thirtieth of a second to one second or more, depending on the speed of sending. This refers only to manual sending, as high speed machine sending is not ordinarily used in connection with the telephone circuits.

SIGNALING CIRCUITS

Besides the currents above described it is usually also necessary, on a joint telephone and telegraph circuit, to employ a current for telephone signaling purposes, but as this signaling current is not on the wires at times when the circuit is in use for talking, it is customary to operate the signals by alternating current of a periodicity within the telephonic range.

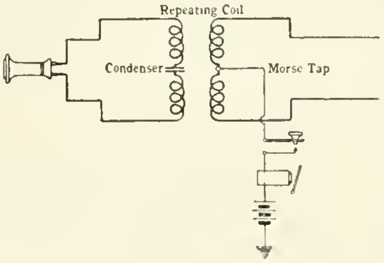

FIG. 1—STANDARD SIMPLEX

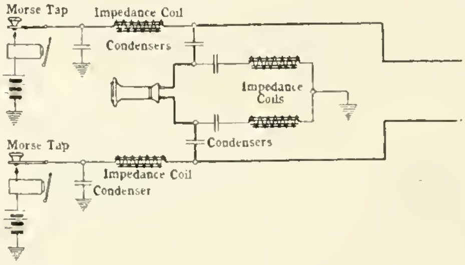

FIG. 2—STANDARD COMPOSITE

PREVENTION OF INTERFERENCE

The prevention of interference between the telephone and telegraph currents is a problem not of the line itself, but of the arrangement of transmitting and receiving devices at the terminals. The currents do not interfere with each other in their propagation over the line. The conditions essential to non-interference are:—

1—That the telegraph transmitting devices may impress Morse currents on the line without disturbing the telephone transmitting or receiving stations, and conversely.

2—That the telephone transmitting devices may impress telephone currents on the line without having these shunted into the telegraph instruments to a harmful extent. The last named condition is set up, not because of fear that the telephone currents would interfere with the operation of the telegraph instruments, but in order to minimize impairment of telephonic transmission efficiency.

COMBINATIONS

The two most common forms of combining telephone and telegraph operation are the *simplex* and the *composite*. The simplex affords one Morse circuit, the composite two Morse circuits per telephone circuit; i. e., per pair of wires.

Simplex—In the simplex system, shown diagrammatically in Fig. 1, the telephone circuit is kept balanced and symmetrical so that the mid-point of the line winding of the repeating coil, where the Morse tap is connected, is always a point of zero potential in respect to telephone currents. Thus there is no tendency for the telephone currents to flow into the Morse tap. The telegraph currents in flowing from the Morse tap to the line, or *vice versa*, divide equally between the two symmetrical halves of the repeating coil winding and the two opposing voltages induced in the telephone circuit exactly neutralize each other. The effect on telephone transmission of adding the simplex repeating coils is too small to be detected by the ear, the energy losses in these coils having been minimized by refinements in design and construction. The simplex furnishes a highly efficient telegraph circuit, and is often employed where there are enough line wires available to permit the use of two wires for each telegraph circuit. A simplex circuit may be operated by any of the standard telegraph methods—single line, duplex or quadruplex. Duplex and quadruplex telegraph circuits are circuits arranged for sending simultaneously two and four telegraph messages, respectively, over one circuit.

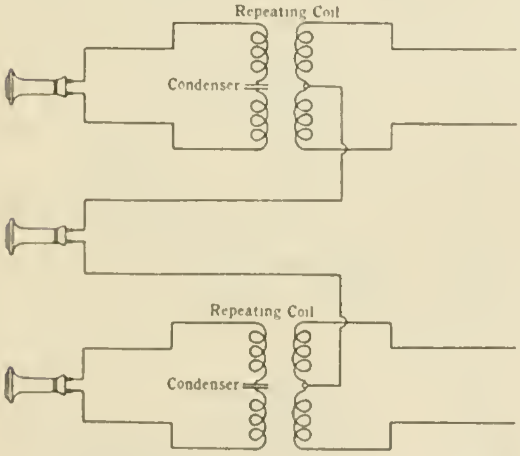

FIG. 3—TELEPHONE CIRCUITS WITH PHANTOM SUPERPOSED

Composite—The purpose of the composite is to prevent telegraph currents from interfering with the telephone currents, also to prevent the telephone currents from leaving their own circuit and getting into the telegraph apparatus. The method which has been found by experience to accomplish these purposes most satisfactorily is that shown diagrammatically in Fig. 2. Interference is avoided by a somewhat elaborate scheme of balancing with condensers and impedance coils. The exact proportions giving best results have been determined by experience rather than by theory. This arrangement is a compromise between that which would most effectually keep the Morse thump out of the telephone circuit and that which would least impair the telephonic transmission efficiency. The standard composite accomplishes both of these objects very well, the effect on the talking efficiency being about the same as with the simplex, and the Morse thump is so thoroughly eliminated as to be inaudible in the telephone under ordinary working conditions. Short lengths of composited line may be worked quadruplex, but in general composited circuits are restricted commercially to single line or duplex operation.

Phantom Circuits—The best examples of economical use of wires are those involving phantom telephone circuits. By means of suitable repeating coils two telephone circuits (four wires) can be made to afford three metallic telephone circuits. The manner of accomplishing this result is shown schematically in Fig. 3. Each side of the phantom circuit is formed in the same way as a simplex telegraph circuit. However, it must not be inferred that the phantom telephone circuit is as easily applied as the simplex. It was many years after the simplex was invented and in use before repeating coils were developed which were sufficiently well balanced and efficient to make "phantoming" possible.

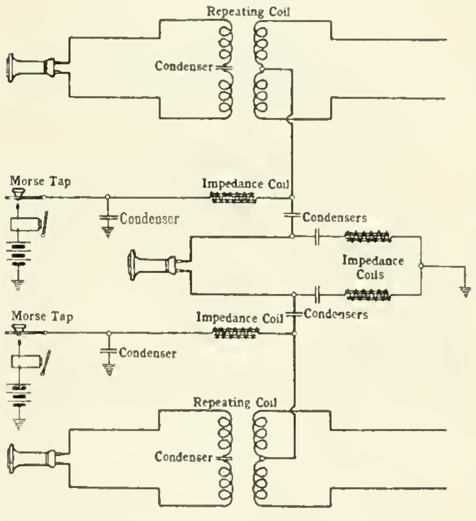

FIG. 4

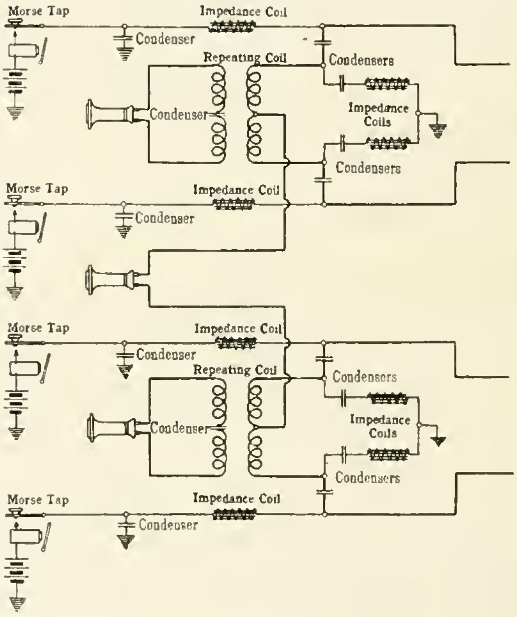

FIG. 5

FIG. 4—PHANTOM TELEPHONE ON SIMPLEXED CIRCUITS WITH COMPOSITE ON PHANTOM

FIG. 5—PHANTOM TELEPHONE ON COMPOSITED CIRCUITS

Morse on Phantoms—Given a pair of phantomed telephone circuits, there are two methods of superposed Morse in use. One of these methods, shown in Fig. 4, consists in applying the standard composite to the phantom circuit. The two Morse circuits thereby obtained may be worked duplex, in which case four telegraph messages may be transmitted simultaneously with three telephonic messages. The second method, which is somewhat superior to the foregoing, is shown in Fig. 5. In this case each wire is composited so that from the four wires are obtained three telephone circuits and four telegraph circuits. As each telegraph circuit may be duplexed, a total of 11 independent simultaneous messages is possible.

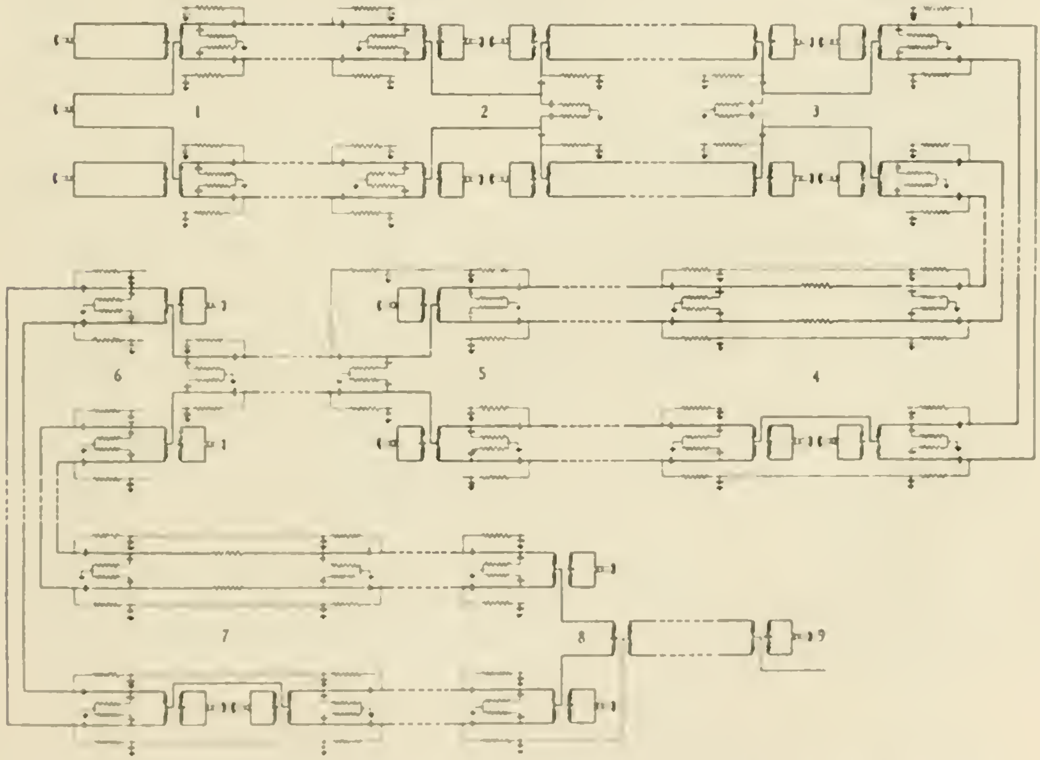

FIG. 6.—COMBINATIONS OF COMPOSITE, SIMPLEX AND PHANTOM CIRCUITS

Circuit Combinations—These three devices, the simplex, the composite and the phantom, offer opportunity for a wide variety of circuit combinations. Circuits to cover great distances may be built up by connecting together lines working independently between intermediate points. An example of this sort is shown in Fig. 6 which will give an idea of the various possible combinations.

The above discussion will indicate some of the possibilities of increased efficiency and economy in the public service afforded by coöperation between these two systems of communication.

MAXIMUM LOADS OF TRANSMISSION LINES

H. B. DWIGHT

THE recent increases in the lengths of transmission lines and high-tension networks have made the cost of the line itself the item of most importance in planning a large transmission system. The question, therefore, arises: With how cheap a line or with how few lines can a given block of power be transmitted? Or, in other words: What are the limits to the loading of a transmission line. In the present article, the various factors limiting the loading of a transmission line are outlined and their relative commercial importance is indicated, so as to show what calculations of electrical characteristics and costs should be made in determining the proper line for a given case. A distinction is made between items which are a serious economic disadvantage, and others which, while presenting engineering difficulties, do not greatly affect the costs if the difficulties are properly taken care of.

The amount of power which any transmission line can carry is always increased if the operating voltage is raised. The theoretical limitation to the voltage is imposed by the formation of corona on the conductors, since if the voltage is raised beyond the point at which corona appear, the energy loss due to the corona quickly reaches a prohibitive amount. The limiting operating voltage depends on a great many factors, among which are the size and spacing of conductors and the altitude above sea level.*

VARYING-VOLTAGE LINES

The usual method of controlling a transmission line is by adjusting the generator voltage so as to give uniform voltage at all times at the receiving end of the line. This may be called the varying-voltage method of control, since at all points on the line, except one, the voltage varies as the load changes. The limit of the load which the line may carry under those conditions is set by the maximum allowable variation in voltage. The maximum variation may be taken as 20 percent, since power cannot very well be sold to a customer, or the station apparatus satisfactorily operated, where the variation in voltage is greater than this amount.

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*The subject of corona has been thoroughly described before the American Institute of Electrical Engineers. See "The Law of Corona and the Dielectric Strength of Air." I, Trans. A. I. E. E., 1911, p. 1889; II, Proc. A. I. E. E., June, 1912; III, Proc. A. I. E. E., June, 1913, p. 1337.

In most transmission lines the reactance is greater than the resistance, and is the chief cause of voltage variation. Any addition to the reactance reduces the amount of power which can be delivered. It has been found advisable in large systems to install high-reactance coils to protect the station apparatus from the effects of short-circuits and surges in the line. The use of such reactance coils with a varying-voltage line directly reduces the maximum load of the line. Since in ordinary cases the voltage variation due to reactance and resistance becomes excessive before the energy loss reaches a serious amount, the cost of energy for line losses does not set a limit to the amount of power transmitted by a varying-voltage line. In other words, the full-load efficiency of such lines is generally high.

TABLE I—VARYING VOLTAGE LINES, NO SYNCHRONOUS CONDENSERS USED

	Line 200 miles in length, with transformers and protective coils at each end	Short line of same electrical characteristics, but without capacity
Frequency, cycles	60	60
Maximum voltage at generator end	115 000	115 000
Minimum voltage at generator end	92 000	92 000
Steady voltage at receiver end	108 000	92 000
Kilowatts delivered	10 100	8 200
Power-factor of load, lagging, percent	85	85
Efficiency of transmission at full load, percent	95	93
Generator k.v.a. at full load	11 900	12 100
Power-factor at generators, lagging, percent	89	73
Generator k.v.a. at no load with normal voltage at receiver	10 400	0
Approximate voltage at receiver end when the receiver circuit breakers open, enough generators being connected to carry the charging current	200 000	155 000

Conductors—250 000 circ. mils. copper cable.
Spacing of conductors—10 feet, flat spacing.
Mean spacing of conductors—$\sqrt[3]{10 \times 10 \times 20} = 12.6$ feet.
Resistance of line per conductor—45.7 ohms.
Reactance of line per conductor—160 ohms.
Capacity susceptance of line per conductor—0.00107 ohms.
Resistance of transformers and protective coils at each end, referred to high tension—4.1 ohms.
Reactance of transformers and protective coils at each end, referred to high tension—64.5 ohms.

The characteristics of a typical line are shown in Table I.

Usual amounts of reactance are assumed for transformers and protective coils at the ends of the line. The load to which power is delivered is assumed to be an ordinary city load with a power factor of 85 percent. In a line 200 miles long the charging current, due to the condenser effect of the conductors, assumes a large value, and it is useful to determine whether this current is a help or a hindrance. For this purpose, Table I shows also the results of the calculations when the line is assumed to have no charging current. This is equivalent to considering a line of, say, 30 miles in length, which has, due to a different size of copper and different protective coils, exactly the same number of ohms of resistance and reactance as the 200-mile line. From Table I it is seen that with the charging current more power can be transmitted and the generator power factor and the transmission line efficiency are higher. As far as the above points are concerned, the charging current is evidently advantageous.

It is often complained that, owing to the charging current, full k.v.a. must be carried by one or more generators when no power is being delivered at the receiver. This does not seem a very reasonable complaint, for no great expense is involved and, as shown by Table I, the gains due to the charging current at full load more than compensate for the losses at no load. The charging current really improves the load factor, making it easier for the generators at times of heavy load, and adding to their load at other times.

A phenomenon to be noted in transmission line operation is the rise in voltage when the load is suddenly disconnected, the excitation of the generators being for the time unaltered. This occurs when the circuit breakers at the receiver end open. The example in Table I shows that at such a time the voltage on the line may rise to a steady value of approximately twice normal voltage. While this is a considerable strain on the insulation of the line and the station apparatus, it is to be remembered that even greater strains are often imposed by the high transient voltages caused by lightning or the opening and closing of circuit breakers. It is also shown by the example in Table I that the increase of line voltage on the opening of the circuit breakers at the receiver end is greater when there is charging current than when there is none, as in a short line. The percentage regulation of a generator between a lagging load of low power factor and no load is not nearly as large as the regulation between a lagging load and full load with leading current. In the latter case the leading current magnetizes the generator to a rather high voltage.

In addition to the generator regulation, there is a rise in voltage along the line when there is charging current, due to the Ferranti effect. By this effect, when the receiver end of a line is not connected to any load, the voltage at that end is a certain percentage higher than the voltage at the generator end. Since the receiver end is disconnected, the only current which is possible must flow into the transmission line as into a condenser, and it therefore leads the voltage in phase. The transmission line along which this leading current is flowing contains reactance, and there will accordingly be a rise in voltage due to the current.

The phenomenon of the increase of voltage when load is thrown off is not to be considered a limitation to the loading of tarnsmission lines. The increase may be very great on a line carrying only a small load supplied by a single generator. The same line may have a smaller increase in voltage, when its load is several times as great as before, if enough generators are used. If the increase is very marked, it can be minimized by keeping enough generators on the line to carry the charging current easily, even at high voltage, in case the receiver circuit breakers open, and by arranging for close regulation of the generator voltage. If the above precautions are not taken, this phenomenon may in some cases prove to be as dangerous as the transient voltages which are such a well-known cause of troubles in transmission systems.

Although the voltage rise may be almost as great on a 60-mile line as on a 200-mile line, it has not as yet proved to be a very serious difficulty in line operation. Since it is exaggerated by the charging current, the latter must be considered to be a disadvantage in so far as the phenomenon of voltage rise is troublesome.

CONSTANT VOLTAGE LINES

The use of synchronous condensers, by means of which transmission lines can be operated at constant voltage and with largely increased loads, is coming into prominence, as it effects distinct improvements in service and large savings in transmission line costs. The study of such lines is comparatively new, and the limitations to loading must be looked at from fresh viewpoints. Constant voltage operation involves the installation of synchronous condensers in large quantities at the receiver end of the line, under the control of the operating company. Their excitation is varied so as to furnish enough leading current to overcome the effect of the load current. It is well known that leading current, such as is furnished by synchronous condensers, tends to cause a rise of voltage in a transmission line. By this means, the voltage at both the generating and receiving ends may be kept steady. The voltage at intermediate sub-stations may be kept constant in the same way, if synchronous condensers are installed there.

Although the cost of the synchronous condensers is large, the extra expense is in many cases justified, especially with long transmission lines, because it results in large savings in the cost of the line itself. For instance, the use of synchronous condensers more than doubles the capacity of a line for carrying power; in other words, for a given amount of power, a cheaper line or fewer lines will suffice. This is due to a change in limits. The limit of voltage variation of course does not apply, since the voltage is kept steady, and so the amount of power can be increased until the energy loss becomes too great for good economy or, as sometimes happens, until the cost of required number of synchronous condensers becomes excessive. In the example shown in Table II, the energy loss limit becomes operative, for 85 percent is a rather low efficiency for a transmission line.

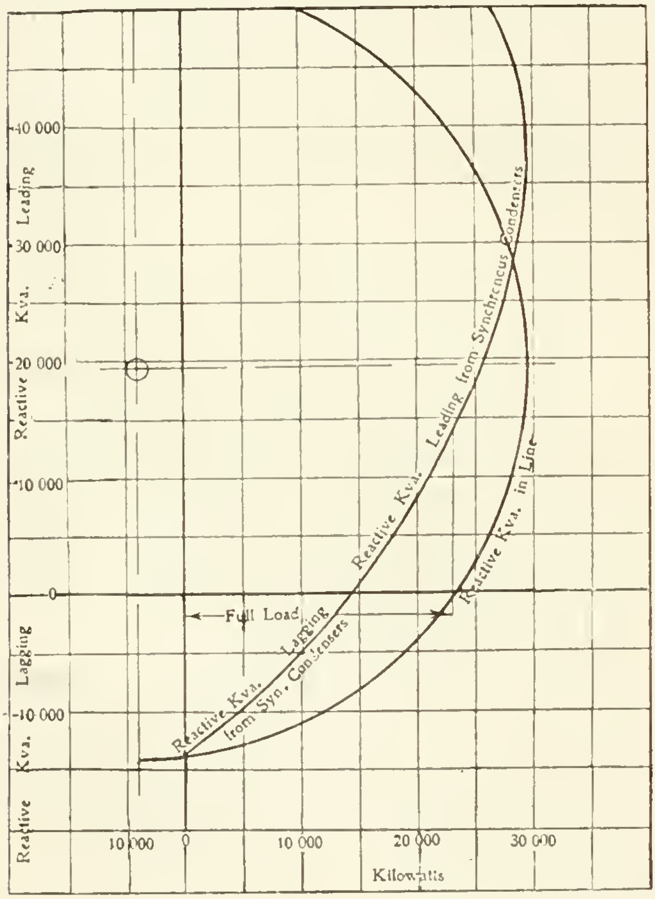

FIG. I—DIAGRAM FOR CONSTANT VOLTAGE TRANSMISSION LINE

In Fig. 1, a curve is shown of the k.v.a. in synchronous condensers needed at various loads for the 200-mile line described in Table II. In plotting this curve, the abscissae are kilowatts of power delivered by the line. The ordinates are k.v.a. of synchronous condensers required. Allowance has been made for the capacity of the line as a condenser in the calculation, and the curve is found to be part of an ellipse. Since part of the leading reactive k.v.a. furnished by the synchronous condensers is used to correct the low power-factor of the load, the curve of reactive k.v.a. actually in the transmission line is different from the synchronous condenser curve, as may be seen from the figure. This latter curve may be shown to be a circle, even when the charging current is allowed for.

TABLE II—CONSTANT VOLTAGE LINES, NO SYNCHRONOUS CONDENSERS USED

Same line data as given for Table I.

	Line 200 miles in length with transformers and protective coils at each end	Short Line of same electrical characteristics, but without capacity.
Frequency, cycles	60	60
Constant voltage at generator end	115 000	115 000
Constant voltage at receiver end	81 000	81 000
Efficiency of transmission at full load, percent	85	85
Kilowatts delivered	23 100	21 100
Power-factor of load, lagging, percent	85	85
Synchronous condensers required at full load, k.v.a.	13 900	15 800
Synchronous condensers required at no load, k.v.e.	13 000	9 500
Generator k.v.a. at full load	29 600	30 300
Power-factor at generators, lagging, percent	92	82
Theoretical limit of load, kilowatt	29 600	27 600
Generator k.v.a. at no load and at normal voltage	7 100	13 500
Approximate voltage at receiver end when the receiver circuit breakers open, enough generators being connected to carry the charging current	200 000	150 000

The curve of synchronous condenser k.v.a. is seen to bend rapidly upward when the load is increased beyond 25 000 kilowatts. The load approaches a limit of 29 600 kilowatts. More power than this cannot possibly be delivered by a line of the specified impedance and supply and receiver voltages, no matter what assumptions are made regarding efficiency or number of synchronous condensers. This limit may be called the theoretical limit of the load. Before the theoretical limit is actually reached, the proportionate cost of synchronous condensers becomes excessive, and the load cannot therefore be economically increased. It is in this way that the effect of the theoretical limit is felt in actual practice. The number of synchronous condensers can sometimes be decreased by lowering the receiver voltage, so as to use as many condensers at no load as at full load. The example in Table I shows about as If a higher receiver voltage is desired, all that is needed is to sup- low a receiver voltage as would generally be considered desirable. ply more synchronous condensers for use at full load.

The 200-mile line described in Table II is typical of most transmission lines in that the theoretical limit is not nearly approached, but the load transmitted by the line is limited by the cost of power for line losses. However, where the cross-section of the conductors is very large, and where large protective reactances are used, the efficiency is high for loads close to the theoretical limit. For such lines, the maximum load is settled by the theoretical limit. Lines with such a high ratio of reactance to resistance as this are rather unusual at the present time, as they would not be economical for the usual varying-voltage method of control, but would be likely to be designed only for constant-voltage transmission.

The addition of protective reactance coils directly reduces the theoretical limit of load, but it does not increase the losses to any great extent. Since most practical lines have excessive losses before the theoretical limit is approached, it is evident that high protective reactances can be used economically on constant voltage lines. For the same reasons, the high reactances encountered with the frequency of 60 cycles are not a very great disadvantage, and the frequency of 60 cycles is, therefore, put on an equality with 25 cycles for economical transmission work, by using the constant voltage method of control.

The excessive rise in voltage when the receiver circuit breakers open occurs with constant voltage lines as well as with those operated with varying voltage. The same remarks apply to this phenomenon as were made in the discussion in connection with varying voltage lines, namely, that it does not affect the maximum permissible load, and that it can be taken care of with proper precautions.

As was noted in connection with varying voltage lines, the charging current is in some ways advantageous, and in some respects disadvantageous. It is not of very great commercial importance in planning transmission lines, although it requires considerable attention and care for its proper control. With constant voltage lines, it increases in some measure the amount of power which can be transmitted at a given efficiency and voltage, and it also tends to raise the generator power-factor. On the other hand, it increases the rise in line voltage when the circuit breakers at the receiver end open.

SUMMARY

For transmission lines, the line voltage is limited by the phenomenon of corona.

The limit of the load on a line operated without synchronous condensers is variation in voltage.

The load limit for a line operated at constant voltage by means of synchronous condeners is much larger than the above limit, and the limiting condition is usually low efficiency.

For heavy lines, with large reactance, or where the cost of power for line losses is low, the theoretical limit for constant voltage lines may be approached, which will involve increased cost of synchronous condensers.

The charging current is of small commercial importance, even though it may be large in amount, and must be carefully allowed for. In general, it is a help; its main disadvantage is that it increases the voltage rise when load is suddenly disconnected from systems not closely regulated.

ELECTRIC LOGGING IN THE WEST

WIRT S. SCOTT

THE SUCCESSFUL adaptation of electricity to any industry depends upon a knowledge of that particular industry, as well as upon a knowledge of the apparatus available and its characteristics. In almost every case the advancement in economical operation produced by the application of electricity to any industry is a true indication of the relative knowledge the electrical profession has of that industry.

Logging in the West was formerly carried on with ox teams. In the last few years these have been superseded entirely by portable steam engines or "donkeys." Within the past two years the subject of electric logging has been given an impetus by a series of tests made on the property of the Smith-Powers Logging Co., of Marshfield, Oregon. While these tests demonstrated beyond a doubt that electricity could be adapted to this industry, yet the results were not altogether satisfactory and convincing to the loggers. The generator from which the motor received its power was not much larger than the motor, consequently when heavy peak loads came on the motor, the voltage dropped at times to as low as one-half of normal voltage, causing a much greater reduction in torque of the motor, which is readily understood by electrical engineers, but not so easily grasped by the non-technical mind.

At the fourth annual convention of the Pacific Logging Congress, several papers on electric logging were read, both by men engaged in logging and in electrical manufacturing. The discussion which followed showed that the loggers were beginningto realize the many advantages of electric power. The main obstacle confronting them was the source of power for operating the motors. The power companies had not, at that time, signified their willingness to build the necessary transmission lines in order to make central station power available, and the loggers were not willing to stand the investment of a power plant for their individual operations, in view of the fact that electric logging is in its experimnetal stage.

Within the past year the power companies have realized the desirability of obtaining a power load on their lines, such as the logging industry offers, and have agreed to coöperate with certain electrical manufacturing companies in demonstrating the practicability of superceding the steam engines by electric motors. The equipment will be especially designed for this work as the result of a study made by engineers of the actual operating conditions in numerous logging camps in the West. It is expected that when this electric logging motor is placed in operation, with the power supplied by a central station, the results will demonstrate that the electric motor can do all that the present steam engine is doing and some additional things besides.

The principal advantages to be obtained by the use of motors are as follows: –

1—Decrease of damage done by forest fires. It has been estimated that at least seventy-five percent of these fires are started by sparks from donkey engine boilers and locomotives.

2—Elimination of burning good fuel under donkey boilers and saving the time consumed in hauling in logs for fuel. Each steam equipment will burn up from eight to fifteen dollars worth of marketable timber per day.

3—With an electric motor only one operator will be required. With a steam equipment, at least two men and often as many as five are required for sawing and splitting wood, firing the boiler, and operating the cable drums.

4—No delays will be occasioned on a long or severe haul due to insufficient steam pressure; also the motor is always ready for immediate operation at any time.

There are other advantages such as decreased maintenance, increased reliability and ease of operation, etc., which no doubt will have much weight in helping to make the electric logging motor an attractive proposition.

The following brief description of the logging industry outlines the various methods used for hauling the logs from the place where the timber is felled to where it is loaded on the cars for transportation to the saw mills.

POLSON LOGGING COMPANY, HOQUIAM, WASHINGTON

The Polson Logging Company, located in the western section of Washington, is considered to be one of the largest loggers of fir timber in the West. The supply of timber which they now control is sufficient to last fifty years at the present rate of logging. Eight separate logging camps are being operated, each employing over one hundred men. Camps are grouped around a main headquarters, about four miles apart, covering an area of approximately twelve miles square. Forty-eight logging donkeys of various sizes and manufacture are in use, operating under three distinct conditions, i. e., yarding, roading and loading.

Yarding Donkeys consisting of two simple, double acting engines, varying in size in these camps from 12 by 12 in. to 12 by 14 in. cylinders, and of approximately 250 brake horse-power, are used for hauling the logs from the place where the trees are felled to a point near the yarder. A five-eighths inch steel trip line is run from the secondary drum of the donkey, looped around a section of timber to be logged off, which may be one-quarter of a mile square, and the end brought back to the donkey. The main line consisting of a steel cable 1¼ to 1⅜ inches in diameter is attached to the trip line, which is then hauled in, pulling the main line out into the woods. The main cable is then attached to the log to be hauled in by means of a choker hook, to which is also attached the trip line, which returns with the main cable when the log is hauled in and is then available for hauling the main cable out into the woods again.

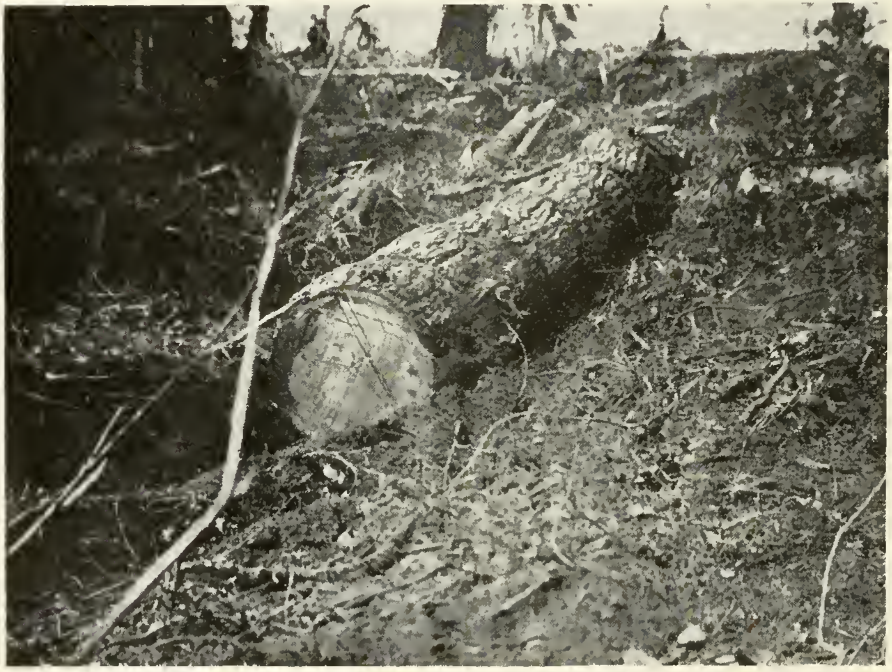

FIG. 1—YARDING A FIR LOG 5 FEET IN DIAMETER BY 40 FEET LONG
Note the trench made by the log plowing through the ground.

The Roading Operations are performed by the use of two and sometimes three donkeys, working in relays, depending upon the length of haul, the average distance being about 2 000 feet. A skid way is built from the yarding donkeys to the loading stations, consisting of three logs per section, arranged "V" shaped, one buried in the ground about half way and one on each side, which form a groove in which the logs are hauled. This possesses the advantage of keeping the logs to be hauled in a definite path, and enables the hauling to be done with less power consumption. The donkeys for this duty vary in sizes from 10 by 10 in. to 10 by 12 in. twin engines of approximately 150 brake horse-power.

In roading, the main cable is fastened to the logs which have been hauled in by the yarder, hauled to the first roader which is called a "swing donkey," where the cable is unhooked from the choker. A cable from the second roading donkey is then attached to the choker and the hauling continued in the same manner, from one donkey to the next, until the loading point is reached. The last donkey, which is stationed at the loading point, is called the loading donkey, and all intermediate donkeys between the roader and yarder are termed "swing donkeys."

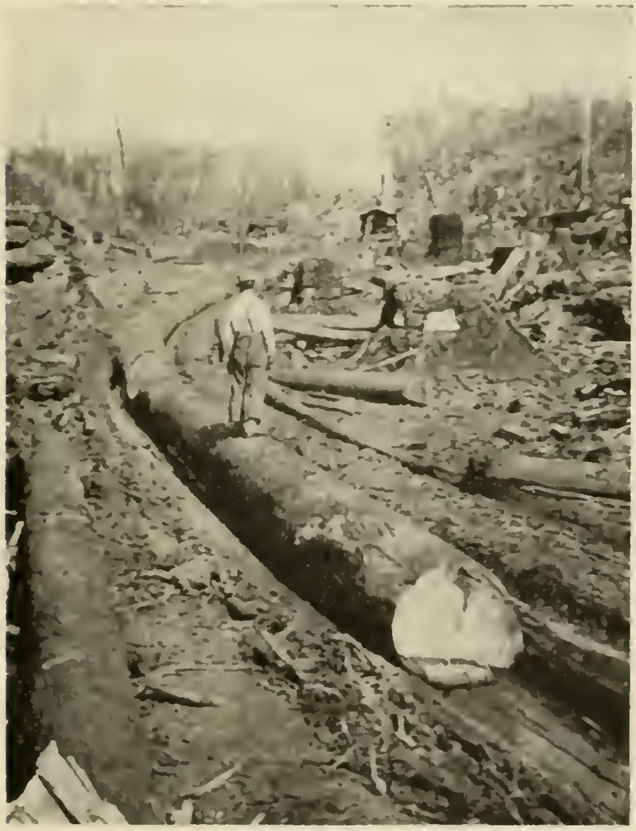

FIG. 2—ROADING WORK

Three logs are being pushed in by the last log, to which the cable is attached. The distance between engines in this instance was about 2000 feet.

Loading Engines are used for picking up logs at the point where they are left by the roading donkey and placing them upon flat cars. Various means are used for raising the logs consisting of swinging boom and masts, upright masts, inclined masts, or two upright masts, one placed on each side of the railway track, with a cable between them, to which is attached the rigging for raising the logs. The engines for this class of work are the smallest type used, ranging in sizes from 6 by 10 in. to 9 by 10 in. twin engines.

Whenever possible, the logs are yarded up hill, that is to say, the yarding donkey is placed at the top of the hill and the logs hauled up. It is claimed by this company that a better control of the logs can be maintained than when logging down hill, and also that the increased power required is offset by a larger output and less cable breakage.

OPERATING CONDITIONS

The following discussion furnishes an idea of the operating conditions required from two yarding equipments.

Equipment No. 1.

One Puget Sound Iron and Steel Works Yarder, with two 12 by 12 in. donkeys, 200 r.p.m., 150 lbs. pressure, 350 horse-power rating.

Main Line—1⅜ in. steel cable
Trip Line—½ in. steel cable
Yarding—1 000 ft.

This yarder was operating under what were considered average conditions for this section of the country. The contours consist of hills and valleys, with a difference in elevation of about 350 ft. The hauling was made up grade as follows:—

550 ft.	18 percent grade
300 ft.	58 percent grade
100 ft.	175 percent grade
50 ft.	10 percent grade

TABLE I—CYCLE OF OPERATION

Time in Seconds			Distance Moved feet	Remarks
Engine operated	Log Moved	Log Stopped		
5		5		Taking up slack
12	12	0		Turning log around in line of direction of pull
		55		Adjusting choker
57	55	100	100	
		125		
				Stuck
23	20		50	
5		50		Stuck
37	35		60	
		145		Stuck
32	30		50	
		50		Stuck
17	15		50	
		145		Stuck
17	15		50	
5		70		Stuck
5		55		Stuck
5		90		Stuck
25	20		40	
		70		Stuck
185	170		600	Total

The cycle of operation for hauling a fir log, four feet in diameter by 32 feet long, approximate weight, 15 000 pounds, is given in Table I. The first 400 feet of hauling was on comparatively level ground, but presented many obstacles in the way of stumps and torn up earth.

Engine in operation	7 min. 15 seconds
Total length of time log was in motion	6 min. 22 seconds
Total length of time log was stopped	15 min. 30 seconds
Total time-hauling in	21 min. 52 seconds
Hauling back trip line	1 min. 55 seconds
Hooking log	5 min. 0 seconds
Unhooked log	2 min. 50 seconds
Total time for complete operation	31 min. 37 seconds
Maximum line speed ft. per min	200
Average line speed ft. per min	157

Equipment No. 2.

Same equipment and location as in Note No. 1.
Size log—5 ft. diameter by 40 ft. long.
Approximate weight—29 000 pounds.

The log was 1 000 feet from yarder and laying at right angles to the line of haul. The choker was attached and the log turned around, when it stuck for the first time. For a distance of 550 feet, hauling was accomplished by a succession of short pulls, requiring 15 minutes for this part of the operation. After traveling 550 feet the engines were completely stalled. It was then necessary to use a single block for the remaining distance, requiring 45 minutes to finish the haul. The total time consumed from the time the log was turned around until the haul was finished was one hour.

The hauling in drum of the donkey had a capacity of 1 500 feet of 1⅜ in. line, and was about two-thirds filled when engines were stalled. It was the opinion of the operating crew that if the drum had less cable on it, the hauling could have been accomplished without resorting to the use of a block. The maximum piston speed recorded was 480 feet per minute.

A 250 horse-power wound secondary motor would give equally as good, and perhaps better service than the steam engine. It is the opinion of the writer, based principally upon his knowledge of steam machinery, that the engine, with the single block arrangement, was operating at approximately three-fourths load. In this event a 300 horse-power motor would have sufficient capacity to meet these requirements without the use of a block.

PACIFIC LUMBER COMPANY, SCOTIA, CALIFORNIA

The Pacific Lumber Company are extensive loggers and saw mill operators of redwood timber. Their saw mills are located at Scotia, Humboldt County, which is also the general headquarters for the logging operations. Six logging camps are operated, the nearest one being 3 miles and the farthest one, 27 miles from the saw mills. Seven hundred thousand feet of timber are logged per day by the six camps, the average number of logs per day being 1 200 for the month of September, 1912, and the average size log being but a trifle over two feet in diameter. The largest log was 10 feet in diameter by 20 feet long, which is the largest size that can be cut in their saw mill. All logs over 10 feet in diameter are split with powder, usually in four sections. This procedure consequently results in a great waste of timber, as it is necessary to square up these sections at the saw mill.

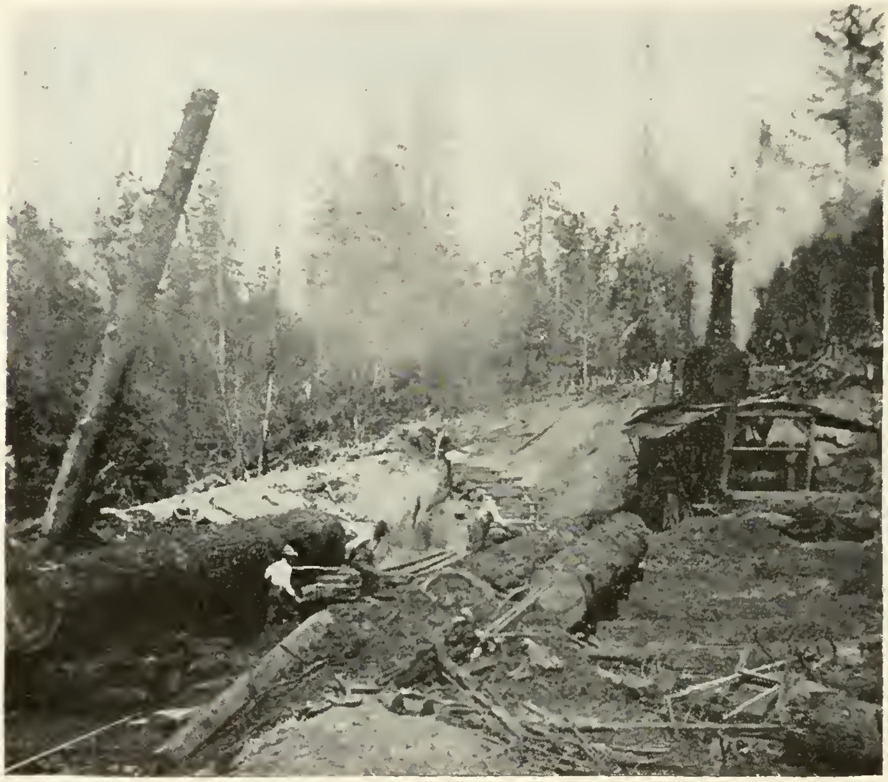

FIG. 3—LOADING THE LOGS ON CARS
Usually three logs are loaded on one car.

Logging donkeys operating at loading stations are supplied with slab wood brought from the saw mills at a slight reduction in cost over sawing and splitting logs for fuel on the grounds. No particular trouble is experienced in burning redwood under the boilers.

Logs were yarded down hill wherever possible. This was done in order to effect a saving in power. The logs were guided to a certain extent by using large pulley blocks located wherever a change in direction of haul was made. As the hauls were, for the most part, very long, it was necessary to have a man stationed at each block to unhook the main line from the choker, pass the cable through the block and hook onto the choker again. This, of course, made it necessary to stop the log each time, while this change was being made.

For signaling to the engineer, a single stroke gong operated by dry batteries was used. Two bare wires are carried over the course operated by the donkey, and the signaling made by short-circuiting the wires. That the operator in the woods may know that the signal has been received, the corresponding signal was answered with the whistle. No trouble has resulted from the use of electric gongs and they have the advantage of being much easier to operate than a whistle wire.

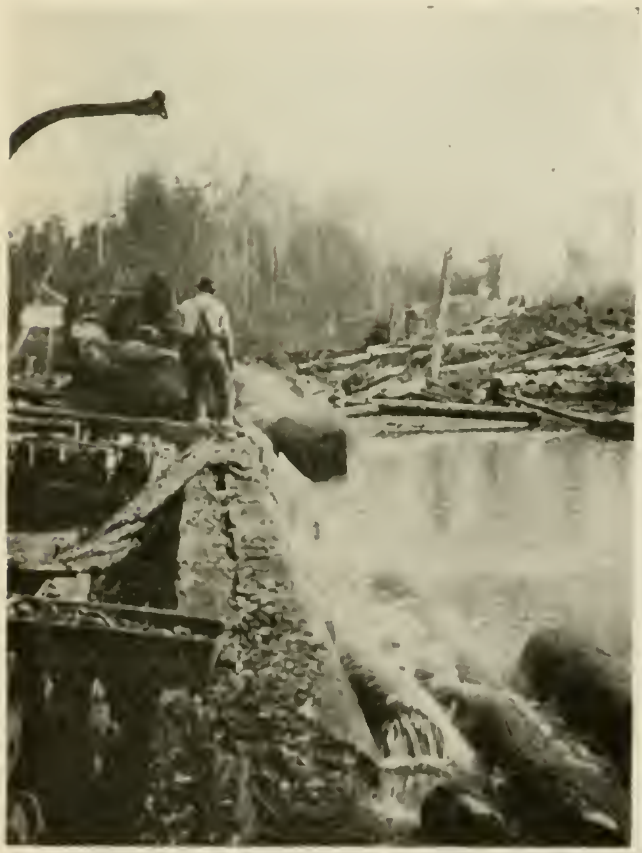

FIG. 4 UNLOADING LOGS IN A POND NEAR THE SAW MILL

From this point they are floated to the log carriage which conveys them into the mill for sawing.

At the present rate of cutting, this company has a supply of timber on hand sufficient to last one hundred years.

POTLATCH LUMBER COMPANY, POTLATCH, IDAHO

The Potlatch Lumber Company of Idaho have in operation two systems of logging—the McFarlane sky line, and a continuous cable system of their own design, which is also an overhead system. The trees in this section of the country are mostly pine, the logs varying from 10 to 30 inches in diameter, and from 20 to 40 feet long. A roadway approximately 50 feet wide is cleared through a section to be logged off. A 1¼-inch steel cable is run out from the donkey, looped at the far end, brought back and secured to a tree at the landing place. Supports for the cable are erected, the cable being placed in straps or hangers constructed in such a manner as not to interfere with a grooved wheel trolley, which rides on the upper side of the cable. The supports vary in height from five feet on the top of the hills to 50 feet in the valleys and are from 300 to 700 feet apart. The log carriage consists of a deep grooved wheel, 12 inches in diameter, and held in place by the downward weight of the rigging.

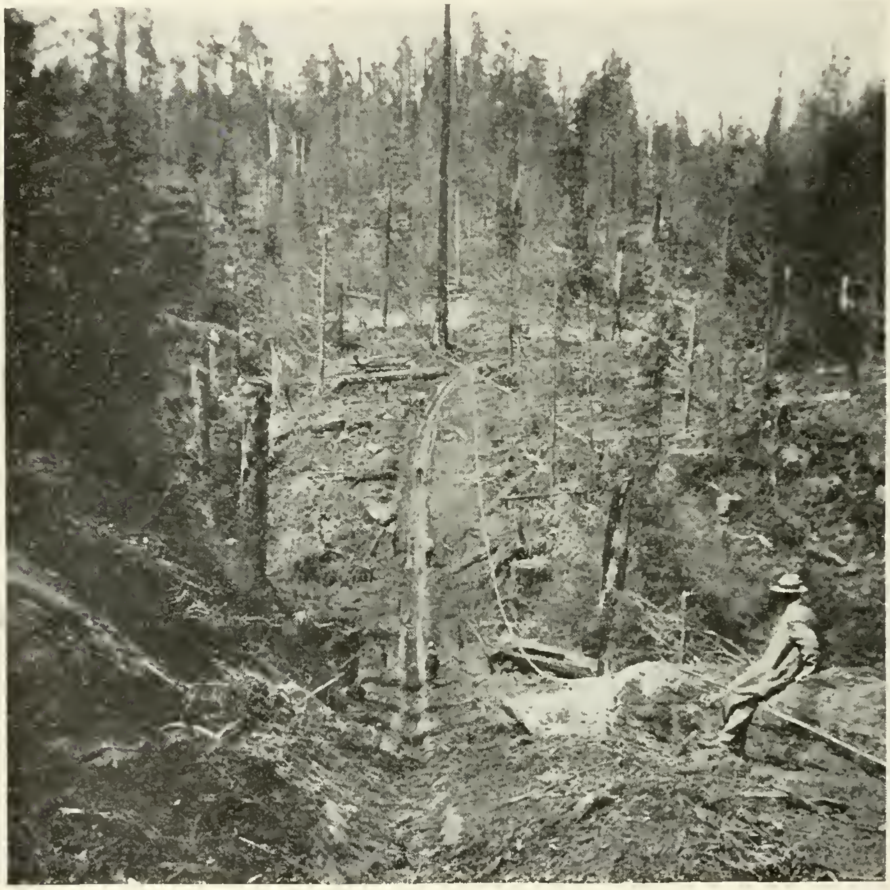

FIG. 5—A ROAD OR SKID-WAY DOWN WHICH LOGS ARE HAULED TO A RAILWAY LANDING

An endless cable, one-half inch in diameter, passes over the drums on the donkey and extends over the same territory as the large cable and directly under it. This cable is placed in grooved pulleys attached to the same supports as the main cable, and travels at a speed of about 500 feet per minute, operating continuously during working hours. The log carriage is attached to the endless cable by a clamp which permits it being fastened and unfastened while running. The log carriages are operated in pairs, one carriage being required for each end of the log. The pairs are kept an average distance of 200 feet apart.

The carriages are placed on the main cable at the unloading point and attached to the endless cable which pulls them out into the woods. At a landing place along the route, two of the carriages are unhooked and taken off the outgoing main cable and placed on the return main cable. The log chains on the carriage are attached to the log or logs, as the case may be, the clamp attached to the hauling in or endless cable, and the logs conveyed to the unloading point.

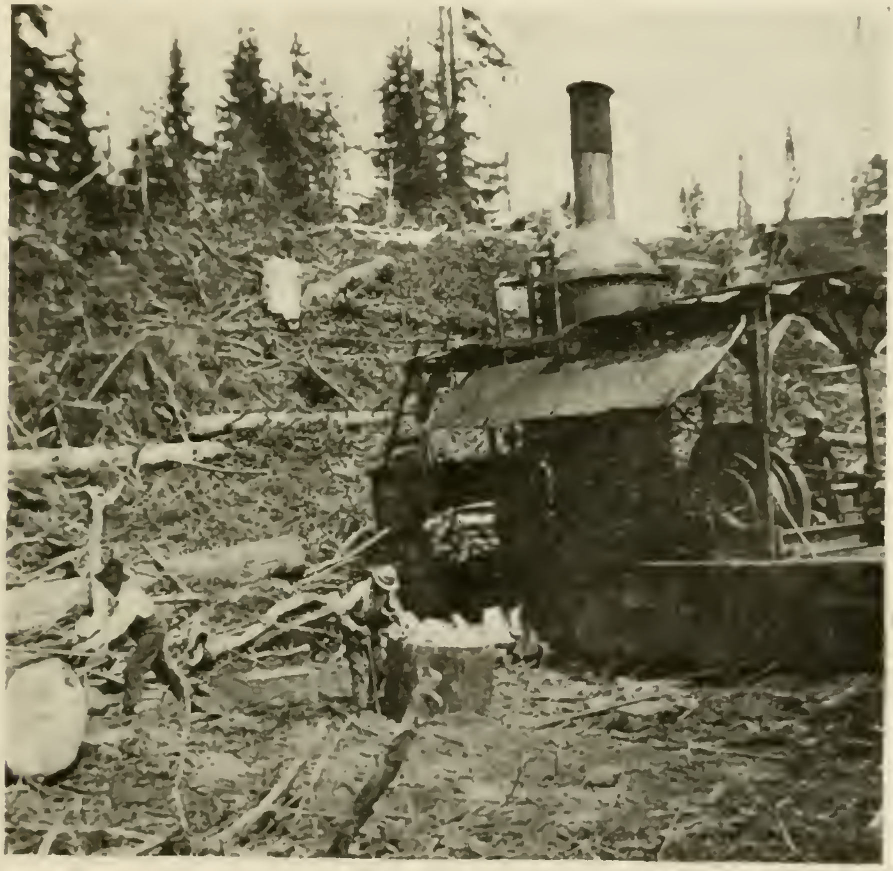

FIG. 6—A YARDING DONKEY

This engine requires the services of five men continuously—one engineer, one fireman, and three wood choppers.

The system as above described, extends into the forest a distance of 6 000 feet, passing over six hills from 300 to 500 feet high. The largest single log hauled was 30 inches in diameter by 32 feet long. Quite frequently two and three logs from 12 to 18 inches diameter would be hauled in at the same time by one set of carriages. With the system in full operation and everything working smoothly, there would be approximately 60 logs enroute continuously. A Willamete roader, with two 11 by 13 in. engines, 140 lbs. pressure, was used for driving the drum containing the endless cable.

At the unloading point for the endless cable system, a derrick was used for picking up the logs and placing them on cars. The object of unloading the logs and again picking them up is to make the proper selection for loading the cars to the best advantage. A Willamette hoisting engine, with two 6¼ by 10 in. cylinders, 140 lbs. pressure, is used for this duty.

At another point of the logging operations of this company, the McFarlane sky line system is in operation. Logs are being hauled a distance of 1 500 feet. A center support is used in this case, dividing the cable into two spans, the longest being 900 feet. Two and three logs are brought in at one time. The main line cable is one inch in diameter and the hauling in cable ⅝ inch in diameter. The cycle of operation was as follows:—

	Minutes
Attaching logs	4
Hauling in logs	4
Unloading logs	½
Hauling back	2
Total time	10½

SKY LINE SYSTEM

Another system of logging, called "sky line logging," is in use, which consists of yarding the logs through the air instead of on the ground, but differs essentially from the method employed by the Potlatch Lumber Company. A main cable is suspended between two trees, known as the head spar tree and the tail tree, usually from 800 to 2 000 feet apart, upon which travels the log carriage. Two lines are required for operating the carriage, one to draw it out into the woods, and the other to haul it in. The choker hook is attached to the log to be hauled in, and then attached to a cable fastened to or passing through the log carriage. In cases where the choker line is attached directly to the log carriage, the main line is lowered while securing the log; the log being raised clear of the ground by taking up on the main line.

Where the line passes through the log carriage and extends to the donkey, the log is raised by tightening up on this line. Usually the choker is attached so that one end of the log is elevated higher than the other, and the log is raised until the highest end clears all obstructions, such as stumps, fallen timber, etc.

Of the various logging systems in use, the method of hauling the logs along on the ground is generally employed. While some companies operate overhead systems exclusively, in the majority of cases at present they are used in conjunction with ground logging.

ELECTRIC OPERATION

An electrical equipment for replacing the steam engines and boilers in the service as described must be very substantially constructed in order to withstand the severe service. It is to be expected that the motors and controlling apparatus will not receive the care and attention usually given to such apparatus, hence it is important that the maintenance be reduced to a minimum, and to accomplish this result, none but the most reliable apparatus is to be recommended.

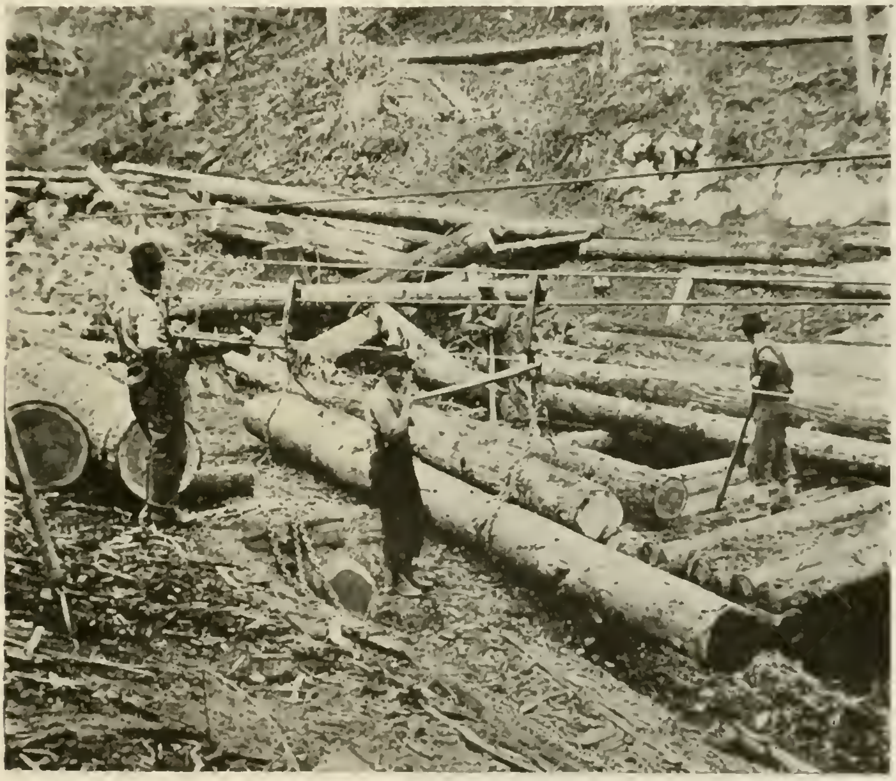

FIG. 7—OVERHEAD ENDLESS CABLE SYSTEM

Three logs are attached to carriages ready to be started in. Carriages are usually spaced 200 feet apart and travel at 500 feet per minute.

For this service a heavy duty, three-phase, 60 cycle, 440 volt, slip ring motor with pneumatic control is recommended. Motors of this type are being offered by manufacturers, which are especially suitable for severe intermittent service, where heavy starting duty is required. The 440 volt windings are chosen in preference to those of the higher voltage in order to obtain the advantages of increased reliability of the low voltage motor under the severe operating and weather conditions to which they are necessarily exposed, as well as to eliminate the possibility of endangering the lives of the operators.

The pneumatic controller which seems likely to give the most satisfactory operation consists of a group of seven air operated switches similar to those which have proven so successful in railway service. Three of the switches are in the primary circuit and four in the secondary circuit, as shown schematically in Fig. 9. The speed of the motor is controlled by a master switch having five speed points. With the master switch in the off position, all of the switches are out. When it is moved to the first point the primary switches close, allowing the motor to start at full load torque with all resistance in the rotor circuit. As the controller handle is advanced, the secondary switches close, one at a time, cutting out corresponding sections of the resistance. The master controller handle may be thrown directly to any speed notch, and the motor automatically accelerated to the corresponding speed. An overload relay is arranged so that in case of an overload exceeding from two

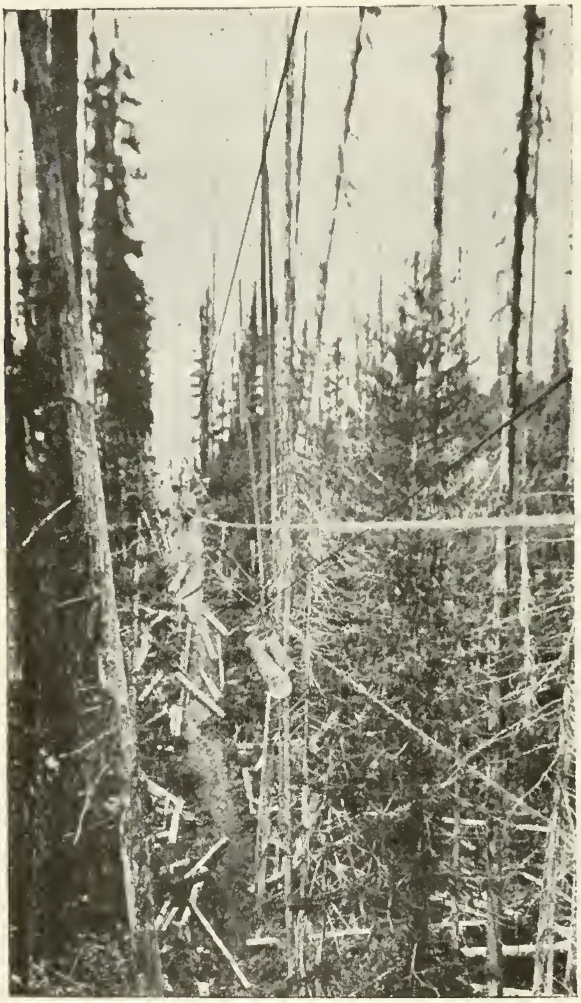

FIG. 8—LOGS SUSPENDED FROM CABLE BETWEEN TWO HILLS

The logs in the background have, from time to time, come unhooked from log carriage and fallen on the side of the hill.

to two and one-half times full load torque, as predetermined, the secondary switches are caused to drop out, limiting the current to full load. This arrangement is of special advantage in logging up hill on a slippery ground. When the log meets an unsurmountable obstacle, such as a large stump, in which case very frequently the log and cable straddle the stump in such a manner that the cable would be pulled in two before the log could be pulled around, it is essential that a tension be maintained on the cable sufficient to keep the cable tight and prevent the log from rolling down hill. If the log should encounter an obstacle as above noted, the motor will automatically come to a stop, but will continue to exert a pull on the cable exactly in the same manner as is done with the steam engine. In order to slacken the cable, the master controller handle is turned to the "off" position, causing the primary switches to drop out, disconnecting the motor entirely from the line.

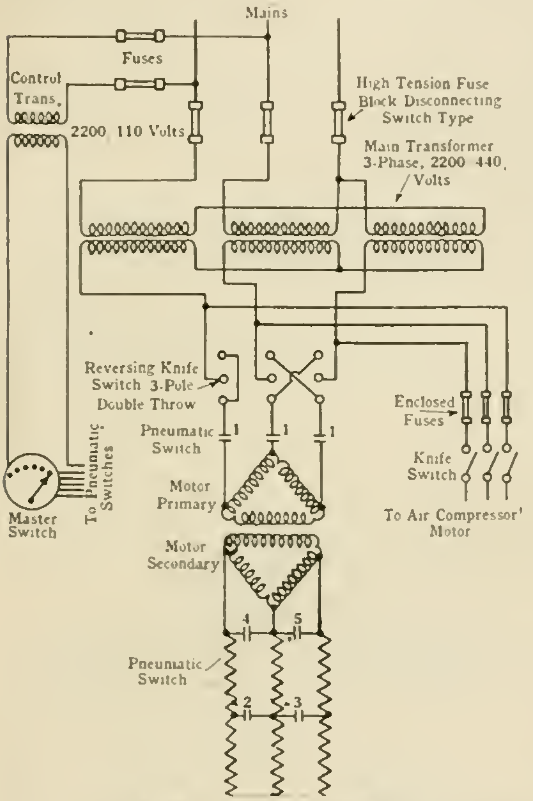

FIG. 9—SCHEMATIC DIAGRAM OF LOGGING MOTOR AND CONTROL EQUIPMENT

As previously noted, the signaling to the men in the woods is done by means of a whistle. With an electrical equipment the use of an air whistle will be required, as it is necessary to signal to the men, who at times may be a mile away. For this purpose a standard air compressor, direct connected to a small squirrel cage motor is used. This compressor also furnishes the air for the pneumatic switches.

THE DESIGN OF ELECTRICAL MACHINES FOR QUIET OPERATION*

G. PONTECORVO

THE importance of quiet operation of electrical machinery in general and especially of motors for applications in buildings other than work shops and factories, is making itself more and more felt, as the use of electricity is spreading every day and invading new fields. In America this is noticed to a greater extent than in Europe as the use of motors for elevator service is more extensive, and the small "general utility motor" for use on fans and sewing machines, has reached practically every home. Besides, the large apartment and office buildings are today using electric motors extensively for such purposes as centrifugal pumps for water service, vacuum cleaners, floor scrubbing machines, etc. To all this must be added the effect of the type of building construction prevalent in this country, such as very high buildings having steel frames which carry the sounds through elevator and air shaft from the cellar right up to the top of the building.

But there are other points which make the design of electrical machinery for quiet operation somewhat more difficult in America than in Europe. It is for instance, practically impossible here to sell alternating current motors for heavy service with anything else than open slots. This is required in order to make repairs to the windings as easy as possible so that break-downs will not interfere for long with the service. Other difficulties which are met in the design of motors (not peculiar to this country, however), are the necessity for using small diameters in order to keep the fly wheel effect as low as possible, and the use of light steel frames, which is becoming every day more prevalent.

It is necessary to note that exact definitions and comparisons of different noises are extremely difficult. The human sense of hearing is very unreliable and scientific methods are of difficult practical use. Besides it is well to remember that experiments carried out by designers in a large manufacturing plant are often made under somewhat unfavorable conditions as the time for experimenting is often very limited. The company with which the writer is connected has built, in the testing department for industrial motors, a special "noise proof room" for the purpose of testing machines under absolute quiet and without interference from extraneous

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noises. This has rendered easier the task of judging whether the noise of a machine is objectionable or not. Experiments were also carried out with graphophones and musical instruments in order to compare noises, but without greater success than obtained with the use of the human ear.

All the different noises produced by electrical machines can be broadly classified as magnetic noise, current noise and windage noise. These three types of noises can be again classified into two main classes, viz: noises which are objectionable and noises which are not objectionable. (Very few machines can be called noiseless in the exact meaning of the word). The above mentioned classifications are all the electrical designer has to contend with in designing a commercial machine. A definition of each of these different types of noises, their origins and remedies, may be of interest.

MAGNETIC NOISE

The expression "magnetic noise" is very wide and goes from a very faint hum to a noise of very high pitch as high as the highest notes in the musical scale. The writer recollects the case of an induction motor producing noises of such high pitch that it could be heard above all the noises of a very noisy factory as clearly as if it were in a perfectly quiet place. In the majority of cases, the magnetic noise is objectionable as it is in general of a very high pitch and carries very far; it is, besides, the most difficult to foresee and overcome when designing a machine. It is due to the vibration of the laminated iron of the magnetic circuit. This vibration is set up by a pulsating field having high frequency and acts in a radial direction; that is, normal to the shaft of the machine.

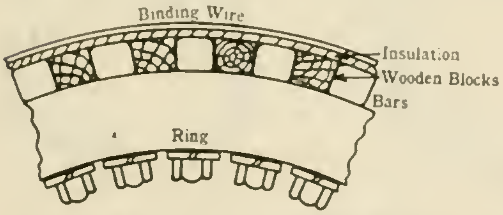


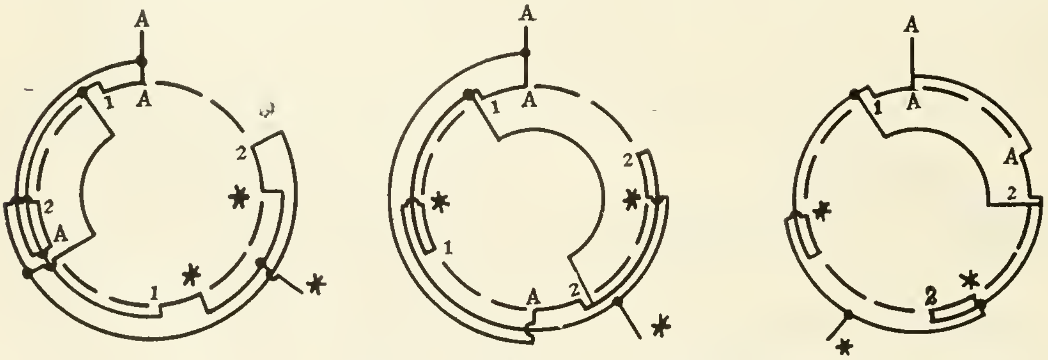
FIG. 1—METHOD OF SMOOTHING THE THE SURFACE OF BARS ON A SQUIRREL-CAGE ROTOR, TO OVERCOME WINDAGE NOISE

CURRENT NOISE

This noise is of an entirely different nature from the preceding one and it is generally accompanied by a vibration of the machine. It is due to the lack of electrical or magnetic symmetry and can be distinguished by its low pitch. Sometimes it sounds low and deep like a growl. Generally speaking, however, it is not as objectionable to the human senses as the magnetic noise, and it is easier to foresee, or to overcome once the machine is built. It is louder at starting under load and differs from the magnetic and windage noises in that, while the other two noises are practically constant at no load and full load, the current noise increases with the load and is often negligible at no load.

WINDAGE NOISE

This is of two entirely different kinds; one due to the large volumes of air displaced by the blowers or fan blades of the rotating part, and going out at high speed through the openings of the frame and brackets. It is of low pitch and generally not objectionable. It is, however, getting more common every day as the ventilation of electric machines is increasing all the time. Another kind is peculiar to induction motors, especially the squirrel cage type, run at high peripheral speed. It is produced by air passing through the bars at both ends of the rotor and through the stator coils or from the rotor into the stator air ducts. It is a whistling noise of high pitch similar to the magnetic noises and very objectionable; it can be distinguished from the magnetic noises by suddenly switching off the current when the motor is running.



FIGS. 2, 3 AND 4—WINDING DIAGRAMS OF THREE-PHASE, FOUR-POLE ALTERNATING CURRENT MACHINES

Showing equalizing connections for three schemes of connection of a two parallel, star winding. For simplicity, connections for one phase only are shown. * indicates neutral points.

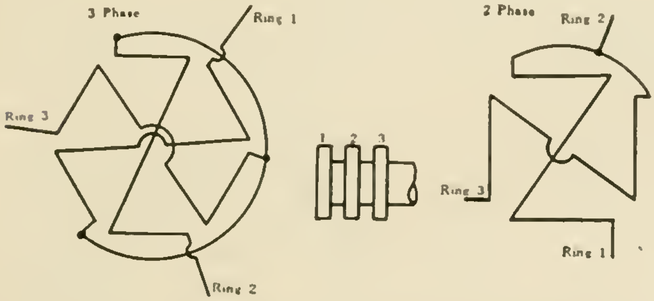
METHODS OF OVERCOMING WINDAGE NOISE

Both of these windage noises are comparatively easy to overcome; the first, by enclosing brackets and when possible by reducing the size and number of blowers, or by some other mechanical device; the second, by smoothing the surface of the bars, as shown in Fig. 1, and by closing the air ducts in the rotor either on the inside or outside surface by means of fullerboard strips.

METHODS OF OVERCOMING CURRENT NOISE

The means of overcoming current noises are various. They consist in getting perfect symmetry and balance both mechanically and electrically. Mechanically, this is obtained by accurate manufacturing and balancing of the rotating parts, by careful centering of stators and rotors and accurate machining of the poles on salient pole machines. On machines with small air gap the grinding of rotor and stator to make the gap equal all around is also necessary in some cases to avoid noises and vibration. Electrical symmetry is obtained by having a symmetrical and balanced winding; for instance, an equal number of slots per pole and per phase on alternating current machines; on direct current machines with six poles, series multiple winding (four parallel) should be avoided.

If, however, on account of design or manufacture, the machine is not quite symmetrical or balanced electrically, the noise and vibration can sometimes be overcome by equalizing connections. The method of making these connections is well known as far as dirct current machines are concerned; on alternating current machines, however, it can be done in many different ways, some of which are not at all effective. Figs. 2, 3 and 4 show three satisfactory ways of using equalizing connections on three-phase, four pole motors. The most effective of these is that shown in Fig. 3. This becomes more evident with a larger number of poles.



FIGS. 5 AND 6—METHOD OF CHANGING WOUND SECONDARY OF AN INDUCTION MOTOR FROM THREE-PHASE TO TWO-PHASE TO REDUCE VIBRATION

To obtain electrical symmetry and reduce noise and vibration on polyphase motors, changing the number of phases on the rotor is very effective. The following two cases are characteristic, the two induction motors in this case behaving in a very similar manner. They were very quiet running at no load but with an increased load they began to vibrate and make noise. The motor characteristics were as follows:—

No. 1—900 H.P., 50 cycle, 12 pole, 500 r.p.m.
Primary, three-phase, 144 slots, star connected.
Secondary, 102 slot wave winding, delta connected.
No. 2—100 H.P., 50 cycle, 16 pole, 375 r.p.m.
Primary, three-phase, 144 slots, star connected.
Secondary, 160 slot, wave winding, star conected.

The large motor could not be loaded more than up to one-half load without danger of damaging the machine on account of the high vibration. By simply changing the connections of the motor from three phase, Fig. 5, to two phase, Fig. 6, (not changing the number of collector rings) the motors ran quite smoothly. Evidently this is due to the fact that the two phase connection on the 12 pole, 192 volts and 16 pole and 160 volts gives a balanced and symmetrical winding. Another remedy is to increase the air gap, Still another one, which is not of great practical value, however, is to supply the rotating part with current and short-circuit the stator.

METHODS OF OVERCOMING MAGNETIC NOISE

The most important of all noises is the "magnetic noise." It is due, as already stated, to a high frequency vibration set up in the magnetic circuit, (stator and rotor). It is a function of the frequency and density of flux and depends on the shape, dimensions and characteristics of the magnetic circuit.

On direct current machines various rules and formulae have been given to prevent noises. However, investigations carried out on direct current machines recently built and carefully tested for noises in the "noise proof room" mentioned above, have not been successful in obtaining any fixed rules. The only result derived from these investigations is, that in order to obtain quiet machines, the shape of the poles should be tangent to the circuit and well rounded at the corners as in Fig. 7. The air gap should be large and the rotor should have at least 1.6 slots per inch of periphery. Another rule derived from this investigation, but which is not a positive rule, is that if, by plotting the slots under the pole as in Fig. 8, it is found that one slot is leaving the pole when another is entering the pole area, the machine is almost sure to be noisy. This tends to show that the noise is due to the vibration set up by the flux at the two sides of the pole. The converse of this rule, however, is not always true.

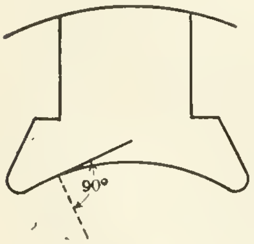


FIG. 7

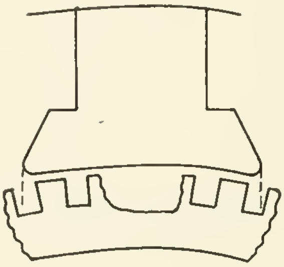


FIG. 8

Fig. 7—The correct pole-tip shape and its relation to pole face curvature for noiseless operation.

Fig. 8—One slot leaving the pole area as another enters it; this relation nearly always produces a noisy motor.

The magnetic noise proper does not vary much from no load to full load. As stated, it depends on frequency and it will be found that for the same density of flux, number of poles, etc., 60 cycle machines are considerably noisier than 25 cycle machines. (Very few 25 cycle machines have been found by the writer to be very noisy, even those having open slots in the stator and rotor and no magnetic wedges.) The density of flux on machines built for quiet operation should be kept rather low; 80 000 lines per square inch in the teeth is a comparatively high figure. Alternating current motors, like direct current machinery, must have a very large number of slots, and no less than three slots per pole and per phase should be used either in the stator or in the rotor.

The importance of field form in connection with magnetic noises can easily be seen from the curves in Figs. 9, 10, 11, 12 and 13, and it has been confirmed by experiments. Figs. 9 and 11 show the field form on a three-phase induction motor, wound with full pole pitch and Figs. 10 and 12 on a motor wound with 83.3 percent of full pole pitch. The maximum variation, *A* to *B*, Figs. 10 and 11, determines the noise. By reducing that variation the noise is considerably reduced and this can be easily accomplished

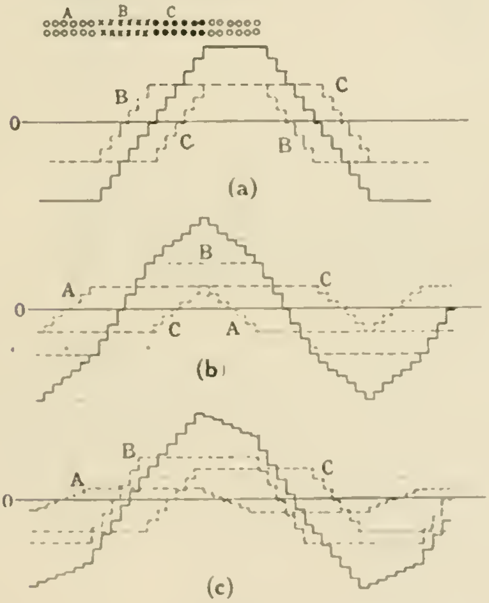


FIG. 9

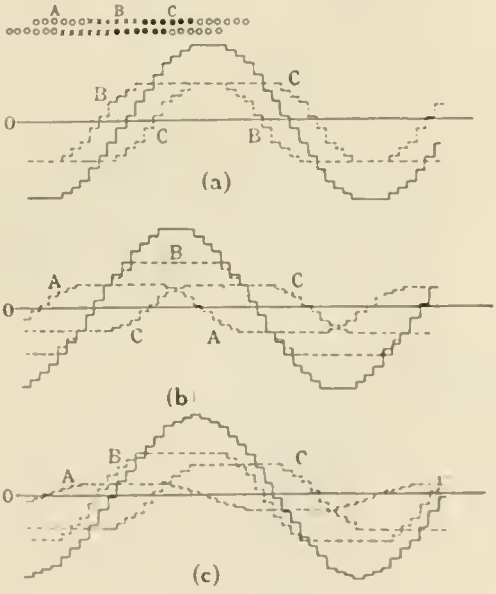


FIG. 10

FIG. 9—ANALYSIS OF FIELD FORM VARIATION

For different coil positions with a full pole pitch winding, showing the effects at three different instants in the cycle as the field rotates.

(a) Phase $A = \cos 90^\circ$. $B = \cos 30^\circ$. $C = \cos 30^\circ$.
(b) Phase $A = \cos 60^\circ$. $B = \cos 0^\circ$. $C = \cos 60^\circ$.
(c) Phase $A = \cos 75^\circ$. $B = \cos 15^\circ$. $C = \cos 45^\circ$.

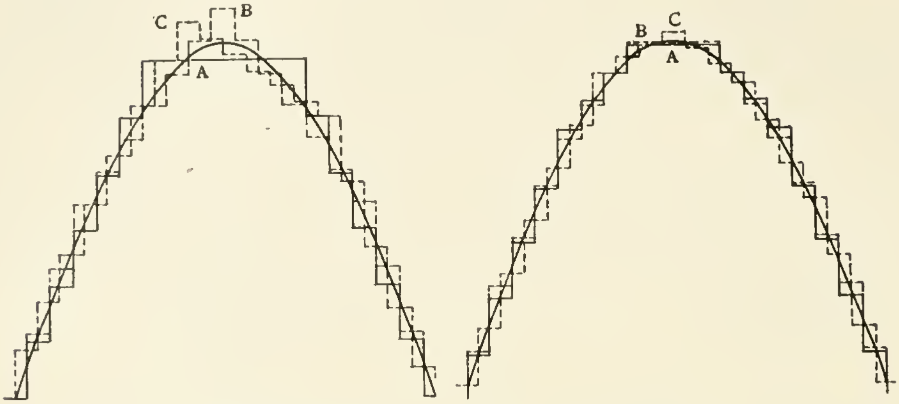
The dotted curves represent the field form due to the respective phases at a given instant. The full line represents the resultant field form at that instant.

FIG. 10—SIMILAR ANALYSIS TO THAT SHOWN IN FIG. 9

Except that the coil throw is 83.3 percent of the pole pitch.

by properly selecting the throw when designing the machine. Fig. 13 indicates the pitch for which this variation is a minimum.

A great help in reducing the noise on machines with open and wide slots is the use of properly designed magnetic wedges. They reduce the intensity of the noise making it less objectionable, by acting as a muffler. The skewing of slots of the rotating part is also of advantage and the reason is obvious, but the skewing should not be too great. The amount of skewing depends, of course, on the primary and secondary slot pitch and last but not least, on the mechanical construction and dimensions of the rotor. A very clear idea of the current and magnetic noises can be had from the tabulation of extensive experiments carried out on large eleva-



FIGS. 11 AND 12—FIELD FORM CURVES

These curves indicate the effect of "throw" on field form variation. The curves (*A*) (*B*) and (*C*), Figs. 11 and 12 are the resultant curves in (*A*) (*B*) and (*C*), Figs. 9 and 10, respectively, superimposed for ready comparison. The magnetic noise is determined by the maximum variation of field form (indicated in this case by the variation between (*A*) and (*B*).

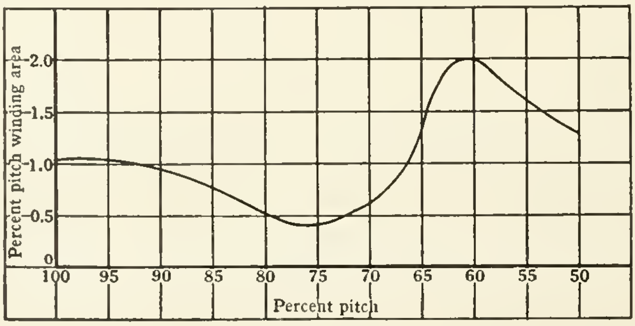


FIG. 13—CURVE SHOWING RELATION IN PERCENT BETWEEN PITCH AND VARIATION OF FIELD FORM AREA

Full pole pitch is 100 percent pitch and the area of the corresponding field form is 100 percent area.

tor motors for quiet operation, in Table I. This table may give an idea of the difficulties encountered in the designing of noiseless motors when using open slots and a rotor of small diameter. If, besides, we take into consideration the fact that a motor with (90 + 71 = 161) slots, has practically the same performance, (torque and efficiency) as a machine with (120 + 90 =) 210 slots, it will be seen that the quiet motor is considerably more expensive, as the cost is a function of the number of slots.

TABLE I—RESULTS OF EXPERIMENTING ON 35 HP, 60 CYCLE, 3 PHASE, 10 POLE, 440 VOLT ELEVATOR MOTORS WITH WOUND ROTORS AND OPEN SLOTS

Primary Slots.	Secondary Slots.	Noise.	Vibration	Comments
72	109	Low pitch	Vibration	Equalizing connections did not help very much except to reduce vibration. Noise objectionable for elevator service.
72	108	Low pitch	Vibration	
90	109	Low pitch	Vibration	
108	109	Very deep	Vibration	
90	71	Low pitch	Vibration	
90	75	High pitch magnetic	None	Noise objectionable for elevator service.
90	75	Less objectionable	None	With magnetic wedges
90	75	Still less objectionable	None	With rotor slots skewed
90	75	No appreciable difference *	None	With cross-connections
120	75	High pitch magnetic noise, still objectionable for elevator	None	With magnetic wedges and skewed slots
120	84	Very slight noise	None	With magnetic wedges
120	90	None	None	O. K.

*This was to be expected from what has been said as to current and magnetic noises.

The subject of noise in electrical machines has so far been very little investigated scientifically, due, as previously said, to practical difficulties. This article only describes some of the difficulties encountered in the designing of alternating current and direct current motors and generators for quiet operation. No doubt, other cases may present themselves, but they may all be covered more or less by the classifications mentioned, and remedies may be found along the lines described.

SMALL TOOLS—THE BASIS OF ECONOMIC MANUFACTURING*

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"Small Tools"—those small, half-forgotten and insignificant objects that are taken as a matter of course in manufacturing. Let us see whether they are unimportant or whether it is true that the efficiency of the larger features in a system is dependent on the efficiency of the small tools; for no matter what the organization may be or aim to be, no matter how vast the scope of its undertakings, no matter how modern the factory installation, back of all are the small tools, pieces of steel fashioned and worked into a thousand different shapes, to turn, to bore, to mill and thus shape the various parts, so that they fit together to form a perfect whole.

THE first knowledge that is needed before proceeding to manufacture any article is the cost of its production. The selling price is dependent to a considerable extent on the cost of tool development, not only to make the article, but to re-produce it in large quantities and to maintain accurate production over a long period. However, before the best type of tool can be determined, there must be at hand definite information as to the demand for the article, which may be of two types:—

1—It may be a novelty that will be sold in large quantities when first put out, but for which the demand will quickly die out. The type of tools for such a product should be the cheapest that will produce the largest quantity for a short period. The cheaper carbonized steels find their places here, for punches, dies and forming tools, machine steel cutters, with not a particle of expense incurred that is not absolutely necessary.

2—It may be an article or piece of apparatus for which the demand will be limited but permanent; that is, the type of apparatus in varying design will be needed over a long period of time, and, the design and character of the tool will of necessity be different and of higher value.

When a new piece of apparatus is being designed, the first thing to be determined is whether the design is feasible. To determine this an experimental model is made, following the drawings as nearly as possible, but made by hand and machine shaping, the sole purpose being to prove that it will work. After completion it is carefully studied, with a view of changing the design wherever it is found possible to cheapen manufacture by the special tool method. When all necessary changes that can be foreseen have been made, the completed drawings are forwarded to the superintendent of the department in which the article is to be made, who in turn studies them for the purpose of determining the number and kinds of tools needed, and these are considered by him from the standpoint of his installation and the kinds of machine tools available. He then has an estimate made of the cost of the tools desired. In all cases except the simplest tools, these tools must be designed and laid out on the drawing board before a reliable estimate can be made. These estimates are forwarded to the supervisor of tools, whose function it is to study the drawings with a view of checking up whether all the tools are included. The original sheets are then forwarded to the department making the request, which in turn forwards them to the management for approval. This is all preliminary work, and as yet no tools are ordered, nor will be, until final executive approval is secured. On the estimates thus made rests the life or death of that piece of apparatus. From them is determined the length of time required to get a return for the first cost of small tools, and this time is in turn determined by the selling value of the product.

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*This is the fifth of a series of articles on the general subject of "Works Management."

Often too little importance is attached to tool estimates. They should be carefully considered and studied, taking into consideration the possibilities for defective work; defective material, which means new parts; defective time, and by that is meant failure to keep promised dates. This last item is more serious than might appear, for all subsequent work is based on the first date of promise of the design drawing of the small tool. Any delay will of necessity be felt in all departments through which the work must go, even to the sales department, as they may have booked orders on the strength of dates of promise. To meet dates made on the strength of this first promise, additional expense is often incurred in over-time, and this invalidates the original estimate.

The subject of tool estimates is one of the utmost importance in small tool work. Estimates are apt to run to both extremes—too low, which means loss of money to the company, and too high, preventing the company from making parts or apparatus on which a profit might be possible. The estimating department should be composed of men who are familiar with machining operations of all kinds.

When the decision has been made to build the apparatus, it is rarely possible to start work on the tools at once, except small tools of standard design that are common to all work, such as drills, reamers, counterbores, countersinks, etc., which can be started without delay. Special tools must be designed on the drawing board. Often this involves the gathering together of a mass of data that would astound the layman.

The cost of small tools forms an expense item not chargeable to the order on which the apparatus is built. This is especially true of reproduction tools, whose chief function is in no wise the economic one. The jig and fixture, the punch and die, and forming tool are not primarily for cheap production. Their principal value is inter-changeability so that products can be marketed in all parts of the world and maintained by repair parts when needed, and these parts must fit accurately. The vast majority of those who only brush up against the product of these reproduction tools, think that, when the engineering department puts out the finished drawings for a piece of apparatus, the tools just grow up from these, whereas there is as much engineering skill required from this point on as there was to bring the drawings of the thing to be built up to a finished stage. It is not the same kind of engineering, but just as scientific, just as accurate, just as valuable an asset to the manufacturing company as the other. Yet it is a fact that the engineering skill required to design a jig or fixture, punch and die, or bender, and to lay out the drawings from which the tools are built, is often not fully recognized as compared with that required in making the drawings of the apparatus itself.

The cardinal points in jig and fixture design are:—

1—Accuracy in reproduction of parts.

2—The time element in handling the work. This involves the completion of the work with one handling, if possible; also the elements of quick clamping, such as for holding cams, etc. The operations to be followed must be known to the designer.

3—Cheapness of construction, considering not only the material but also the pattern work. This introduces the possibility of making a built-up jig of requisite strength and light enough to be easily handled.

In punch and die design, more science and thought must be used, if possible, as the expense attached is very much higher. The type of apparatus to be built does not always aid in determining the kind of die, whether a simple slot die at a cost anywhere from $15 to $150, or a compound die at from $150 to $600 and upwards. The accuracy of the parts as well as the quantities used, are the primal factors. Where large areas are required which, if built solid, would mean special frames with enormous pressures, even though a shearing cut is possible, they are built up in segments of area small enough to prevent shrinkage and change of shape in hardening.

Customs vary in regard to hard and soft dies and punches. There is much ground for argument on both sides; the contenders for the hard punch and die claiming greater accuracy over a longer period of time, although conceding it to be more expensive to build, because greater accuracy is required in the fitting together of the parts, while those who contend for the hard punch and soft die, claim for it, cheapness and low upkeep, inasmuch as the die can be hammered up when needed, with little expense and loss of time.

Coming now to materials of construction, the chief and most important is the tool steel which goes into these tools, for tool steel has character, just as the human being has, and variations in character must be dealt with as we deal with different characters in individuals. In the last analysis, dependence must be placed on it for the maximum output at the least cost of production. This age of rapid production has created its own definite demands, the chief of which is for a steel that will allow faster cutting speeds and feeds. A more scientific knowledge is needed to handle these alloy steels, and that knowledge must embrace the constituent parts of the alloy.

In the carbon steels, the percentage of carbon content only is considered. The proper hardening temperature varies inversely as the carbon percentage, a high carbon steel hardening at a lower temperature than a low carbon steel.

In the alloy or high speed steels, consideration must be given to chemical action of various elements, such as tungsten, molybdenum, wolfram, chromium, manganese, vanadium, and the last to be put on the market, cobalt, for which remarkable results are claimed.

Carbon steel, and by that is meant a tool steel that is dependent only upon its carbon content for hardening, will burn or break beyond a certain temperature, say 1700 degrees F. Way below this, however, is a critical temperature at which the best hardening results will be obtained. This point is determined by means of a small electric furnace pyrometer couple and reading galvanometer. Small pieces of the steel are clamped to the ends of the couple and the temperature rise noted simultaneously with the time between readings of the temperature. This curve on a test case shows a gradual rise up to 1455 degrees F., when the temperature ceases to rise for a period of about 24 seconds. This is called the recalescent point, where the metal has so many heat units, that it cannot absorb quickly any more from the furnace, but feeds on itself as it were, adjusting these heat units within its own body and then continues to rise. Or taking the metal out of the furnace and allowing it to cool, the temperature drops gradually until the decalescent point is reached, when it fails to throw off any of its heat for a number of seconds again, after which the temperature continues to decrease. These two points are important. The recalescent point is the critical temperature at which this steel should be hardened. In re-hardening, when necessary, these two points mark the zone of safe heating temperatures. This is one of the necessary refinements in small tool making. Each brand of carbon steel must be treated in this way before attempting to treat tools made from it, because each tool turned out must be capable of maintaining the same cutting speed and feed, else the time limit, based on a tool of high efficiency, could not be maintained. So here again the small tool bears a definite relation to the system of paying wages. Failure to turn out tools of the same temper and toughness would mean failure to set any standard for paying wages to the men and would force a return to the old day rate system.

The temperature at which carbon steel is heated is about 1450 degrees F. Hardening at this temperature, however, leaves the steel brittle and heat must be put back into it to reduce this hardness and brittleness. This is called tempering and takes place at about 435 to 450 degrees F., hence, any cutting speed that generates more than 450 degrees F. reduces the hardness.

On the other hand, due to a combination of the elements in the alloy steels, and where these elements, and not the carbon, are the hardening elements, a temperature of from 2150 to 2400 degrees F. is needed to get the elements in harmony with each other, after which they are dipped in oil or cooled in a blast of air, and no drawing or tempering is required. With this steel, the speed of the metal being machined can be doubled and trebled without generating sufficient heat to break down the tool. Often they will keep on cutting and doing efficient work when the nose of the tool is red from the frictional heat.

In the small tool field, there is another important factor to be considered, and that is the use, or the differentiation between carbon and high speed steels, i. e., when to use them, and here again very many factors enter to complicate matters. On machines where increased speed is not possible, it might be considered a simple matter to determine that carbon steel should be used in the tool. Yet the work may require an accuracy that the carbon steel cutter could not maintain, due to wear of cutting edge. Furthermore, repeated grindings of the cutting edges means loss of time and production which may be eliminated by using high speed steel.

The difference in price between carbon and high speed steel is from four to six times and there is also a wide difference in costs of high speed steel, from 35 cents to $1.00 per pound. For the benefit of many who have asked whether the more expensive steels pay, Table I is given to show that it does. An extreme case is assumed in which it is shown that an increase in production of one percent is all that is necessary to warrant an increase in tool steel cost of 50 percent. On the face of this showing, the conclusion might be drawn that it would be well to discard carbon steels in small tool production and use only the high priced steels, but high speed steels will not stand shock or jar as do the carbon steels. Sudden cooling is apt to spell ruin to the high speed drill, and every condition arising must be given analytical study because so many things hinge on the performance of these tools, such as dates of delivery, economic production, wage systems and sales. All are dependent on the quality of the steel used in small tools.

Another question that is constantly arising is, "What to buy outside and what to make in the plant?" When the tool making department is unable to meet the demands placed upon it, it becomes necessary to hire another manufactory to do the work. If the demand continues the question comes up, "Why not increase a department to meet the needs?" But are these needs permanent? If not, when dull times come a large machine installation would be idle, and the maintenance cost of this increased installation might be much higher than the increased cost of buying outside.

All of these matters are problems in the small tool system that are worthy of the best engineering minds, and all of the points touched upon establish the fact that the small tool is a vital factor in all that belongs to works management. It will be evident that the shop side of manufacturing offers a field for the young man as big and broad as any field, as there is no limit to the development of the man who takes up these problems and solves them.

TABLE I—DOES IT PAY TO USE THE HIGHER PRICED HIGH SPEED STEELS?

Example:	
High Speed steel, cost, per lb.	\$0.75
Carbon steel, cost, per lb.	0.50
Additional cost of high speed steel	\$0.25
Percentage increase	0.50
Cost of Operating:	
Machinists time, per hour	\$0.36
Overtime, including power	0.24
Cost, per hour	\$0.60
Cost, per 10 hour day	6.00
Problem:	
Shafts, per lathe per day	100
Labor cost, each	\$0.06
Grinding waste per day with six grindings, average ¼ lb. at	
\$0.75	0.18¾
0.50	.12½
Increased cost	\$0.06¼
A saving is generally affected in the number of grindings with high speed steel.	
If only one grinding per day is saved:	
Time taking out tool	½ minute
Going to grinder	1 "
Grinding tool	2–5 "
Returning to lathe	1 "
Resetting tool	½ "
Total	5–8 minutes
Saving 1/12×60 equals \$0.05 per day.	
Saving in Steel:	
Six grindings per day = ¼ lb.	
One grinding = 1/6 × ¼ = 2/24 of \$0.75 = \$0.03.	
If higher priced steeel increases the daily output only one shaft per day, or one percent, the saving will be as follows:	
Total Saving:	
One shaft, increase	\$0.06
One grinding, less	0.05
Saving in steel	0.03
Total	\$0.14
Increased cost of steel	0.06¼
Net daily saving	\$0.07¾

In ordinary practice the saving obtainable by reason of increased output is much more marked than indicated in this extremely unfavorable case.

COPPER—ITS USES IN LARGE ELECTRICAL WORKS

J. L. JONES

IN THE PRODUCTION of electrical machinery and appliances no other metal plays as large a part as copper. On account of its importance as a material for electrical construction, a brief outline will be presented of its physical characteristics, the methods of its production from native copper, from sulphide or other copper ores and from reclaimed copper, its rolling into sheets or drawing into wire, strap, commutator bars, etc., its melting and casting into sand castings, and some of the more important electrical applications of wrought copper.

PHYSICAL CHARACTERISTICS

The electrical conductivity of copper is second only to silver. Its specific gravity when wrought is 8.90, according to the Smithsonian Tables, so that it weighs 555 pounds per cubic foot. Cast copper is more or less porous, although our commercial castings usually show a gravity of 8.88. The fracture of cast copper is granular and irregular while that of rolled or forged copper is fibrous, with a silky luster. Its color is a characteristic red.

Copper is very malleable and ductile and may be drawn into very fine wire or may be rolled into very thin foil. It becomes harder when worked, but by annealing at about 320 degrees, C., it regains its malleability. If forged or rolled copper is heated to a red heat, it may be thrown into water and cooled quickly or allowed to cool slowly in the air, and it will be equally soft, differing in this respect from steel.

Copper melts at 1054 degrees, C., is very fluid when melted, has a sea green color, and, when much overheated, as in the electric arc, is volatile and burns with a characteristic green flame. Volatilized copper is said to be poisonous and to produce symptoms similar to lead poisoning, a case having been recorded where a number of workmen were poisoned while melting copper in an arc furnace.

When heated to a red heat copper unites with the oxygen of the air to form one or both of two oxides, which are known respectively as black and red copper scale or oxide. Black copper oxide is infusible, but red copper oxide melts readily and is soluble in molten copper, making it dry and brittle. The readiness with which copper oxidizes renders it necessary to anneal very fine wire in a closed pot or annealing furnace entirely away from the air.

Copper is not tarnished in dry air, but in damp air, in the presence of carbon dioxide, it becomes coated with verdigris (or basic copper carbonate), which is the familiar green stain seen on statuary exposed to the weather. It is also attacked readily by zinc chloride solution (soldering acid), by sulphur or sulphur gases, ammonia, etc., and to a slight extent even by the soldering flux made from rosin and alcohol. The careless use of zinc chloride solution (soldering acid) and certain soldering pastes is responsible for a great many mysterious breakdowns of insulation, as the zinc chloride is very hygroscopic and the fact that it attacks the copper is shown by the insulation turning green.

PRODUCTION OF COPPER.

Lake Copper—Native copper is found extensively in the Lake Superior region, on the northern peninsula of Michigan. With the exception of a few mines that produce arsenical copper, the Lake copper is of remarkable purity. This copper is seldom found on the market at the present time, most of it being contracted for by the makers of wire, sheet copper, etc. As mined, Lake copper seldom runs over three percent metallic copper, although large masses weighing several tons have been found. The rock containing the finally divided native copper is crushed by stamps, concentrated on jigs and concentrating tables and finally melted in reverberatory copper furnaces, requiring no further treatment than poling* to reduce the oxides and bring it to touch pitch. It is cast into cakes, slabs, billets, ingots or wire bars, which are then ready for subsequent manufacturing operations. Much of the Lake copper is so high in sllver that it is refined electrolytically, the silver being recovered.

The recently issued specifications of the American Society for Testing Materials for Lake copper provides that Lake copper must originate in Northern Michigan and that wire bars must have a resistivity not to exceed 0.15535 international ohms per meter-gram at 20° C. (annealed), 100 percent conductivity being based on copper having a resistivity of 0.153022 ohms. Arsenical Lake copper having a resistance of above 0.15694 ohms, when required for special purposes shall be the subject of special agreement as to arsenic content. Lake copper sold for wire bars must have a purity of 99.88 percent.

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*Introducing poles of green wood into the molten metal.

Electrolytic Copper—The greatest portion of the copper production of the United States does not come from native copper, but from the ores of Montana and Arizona, which consist of copper and sulphur, or copper, iron and sulphur. These ores are usually roasted to remove a portion of the sulphur, arsenic and other volatile impurities. They are then smelted with coke in a vertical furnace producing a matte or compound of sulphur, copper and iron that may contain 30 percent of copper. This matte may be stepped up to a higher copper content in various ways, or it may be run into a Bessemer converter, the iron and sulphur burned off and the resulting coarse or crude copper, which may be 99 percent pure, is cast into anode plates and elctrolytically refined, the resulting electrolytic copper being often superior in purity to Lake copper. The less pure grades of electrolytic copper are known as casting copper and are sold for making brass castings and for uses where a high conductivity is not required. The American Society for Testing Materials specifies the same resistivity and purity for electrolytic wire bars as for Lake copper wire bars, thus placing the two grades of copper on an equal footing. However, Lake copper often commands a somewhat higher price than electrolytic copper.

Reclaimed Copper—Large amounts of scrap wire, coils, copper dust, turnings, etc., accumulate at an electrical works, and as this copper is very pure, it has been found profitable to run it down into ingot copper in a copper refining furnace, rather than to sell it as scrap copper. The only impurities in this class of copper are lead and tin that come from the soldered joints, etc. The tin is readily removed in the refining furnace, as is most of the lead, so that the resulting copper is of sufficiently high grade to be used for any rolling or forging purpose, although not being as uniform in quality as Lake or electrolytic copper. For casting purposes this reclaimed copper is very satisfactory, and it is much purer than the ordinary brands of electrolytic casting copper, as it will average 98 percent conductivity against 90 percent conductivity for ordinary casting copper.

ROLLING AND FABRICATION

The copper cakes used for rolling into sheet copper and the wire bars used for the making of wire are of what is known as "tough pitch" grade. They are cast in open copper molds and are not "overhauled" or machined on the top side as is brass that is intended for rolling. As a result, the cakes and wire bars are usually rough on the top side because of dross and scale, and are full of minute pinholes. The modern practice of using very large furnaces and refining copper in heats of 100 000 pounds or more has made it difficult to keep the pitch uniform throughout a heat. Many refiners, for this reason, claim that a refining furnace should not exceed a capacity of 20 000 pounds. In the rolling operation, the pin holes and other defects are very much elongated and may appear in the finished product as "streaks," slivers, and other imperfections. The side of the sheet that corresponds to the bottom of the copper cake, always presents a better appearance than that which corresponds to the top of the cake.

The furnaces used for heating the copper for rolling are of the reverberatory type, and in a late form used for heating wire bars, the wire bars are elevated on a moving platform, pushed into a sloping furnace by a mechanical charger and descend by gravity, being removed from the bottom of the furnace when at a red heat and going directly to the rolls.

Sheet copper is rolled by what is known as the "Welsh or cross-rolling" system in some mills. In most mills, the "straight-rolling" system is used, which consists in rolling a plate to 0.25 or 0.75 in. thick, cutting it to the proper weight for a desired gauge of sheet. then heating and rolling in packs on finishing rolls to the desired lengths as is done with sheet steel. Sheet copper is coated with an emulsion of guano before commencing to anneal it, and this causes the scale to loosen more readily when the hot copper is plunged into water.

Hot rolled copper is not as smooth or as close to gauge as is required for many purposes, so that much of it is subsequently cold rolled. This makes it smooth, stiff and elastic. To remove the buckles from the sheets, they are clamped in a stretching machine and hydraulic pressure applied in slight excess of the elastic limit of the copper. The sheets are now perfectly flat and they are sheared to remove the marks of the clamps of the stretching machine.

Wire, strap, commutator bars, etc., are rolled down from the original wire bars to a suitable size and then finished by drawing through hardened steel dies. These dies soon wear and fail to retain their original dimensions unless all annealing scale is carefully removed from the copper. This is done by quenching the annealed wire, strap, etc., and then washing it with a hose, using water under 200 pounds pressure. Excessive wear of the dies is also prevented by lubricating them well with tallow, soft soap, or other lubricant. For the finest sizes of wire, the dies are made of diamond instead of steel.

Copper may be extruded but not so readily as brass, and in order to obtain greater density, hardness and accuracy, some special shapes which would be expensive to machine, are extruded and then cold drawn.

Where very large terminals and similar pieces are required, they are forged in the blacksmith shop from billets or ingots that have been made of suitable size. The possession of a copper refining furnace is quite a convenience when pieces of this kind have to be made.

CASTINGS

Many applications are found for high conductivity sand castings of copper, viz., terminals, dampers, collectors, switchboard work, etc., and such castings form a considerable percentage of the output of the brass foundry in an electrical works.

When cast in green or dry sand molds, copper shows a tendency to rise and become porous, hence the production of sound copper castings is a foundry problem of considerable difficulty and requires great care in the making of the molds and the melting and pouring of the copper. The molten copper must at all times be kept well covered with powdered charcoal or some similar material to prevent the formation of red oxide of copper, which has the property of dissolving in the copper, making it "dry" or brittle and producing porous castings. Graphite crucibles are generally used in melting copper for castings. Open flame furnaces are much better, however, as the copper can be melted with less oxidation and it can be conveniently poled as is done in the regular reverberatory copper refining furnace. As a consequence, the copper will require very little further deoxidizing.

In addition to using great care in melting to avoid burning the copper, it is necessary, in order to get solid castings, to use a small amount of some deoxidizing agent such as silicon-copper, magnesium, aluminum or boron to reduce any suboxide of copper that may have been present in the copper originally or that may have been formed during the melting operation. Silicon copper is the most practical and satisfactory deoxidizer for copper. By its use, copper castings of 80 percent conductivity may be regularly obtained and with careful melting and by avoiding any excess of silicon, over 90 percent conductivity may be had. Sound castings, free from blowholes, may also be made by the use of aluminum and magnesium, but these deoxidizers (especially magnesium) are liable to produce dirty castings. A large excess of silicon copper will also produce dirty castings and give a weak brittle copper casting of low conductivity.

In cooling from the molten to the solid state, copper contracts or shrinks very considerably, and if the molds are too rigid or cores too unyielding, cracked castings result. Often invisible hair cracks may be present in a copper casting and may be undiscovered even after machining. When put in use and subjected to working stresses, these hair cracks may then cause a rupture of the casting.

THE ELECTRICAL APPLICATIONS OF WROUGHT COPPER

The largest use of copper in the electrical industry is in the form of wire, ribbon and strap. These forms may be insulated with cotton, silk, asbestos, linen, enamel, treated paper, treated cloth, etc. These insulated coatings may be further treated with paraffine, resins or other water-proofing materials such as asphaltic pitch, etc., or with powdered mica and soapstone. Cotton covered wire is used in field, armature and transformer coils. Asbestos covered wire is used in field, armature and magnet coils exposed to high temperatures and is supposed to stand a "dull" red heat without being destroyed. Rubber insulated wire is used for general service, but the sulphur in the rubber attacks the copper so that the copper must first be coated with tin, which is inert to sulphur. In the winding of coils it is important that the copper be soft annealed. The winder can usually tell whether the wire or strap is too hard by the "feel" of it. It is difficult to show this hardness in figures, but it is best done by ascertaining the true elastic limit.

One of the more recent methods of insulating copper wire for use in winding coils for low voltage work, is by means of a flexible baking enamel. This enamel is not affected by moisture, withstands a temperature of 500 degrees F., without injury, and is much thinner than a silk or cotton insulation. Wire for enameling must be a good grade of soft copper wire and any joints must be identical in softness and dimensions with the rest of the wire and have at least 95 percent of its strength. Any "copper grease" on the wire must be thoroughly removed by drawing through sand, as "copper grease" may run as high as 90 percent metallic copper and this would effect the insulation value of the enamel. Where enameled wire is used for higher voltage work, especially on the larger sizes of wire, a single cotton covering is added.

Where one copper wire has to be connected with another in a coil or reel, it may be done either by electric welding or silver soldering. In electric welding the copper may be burned and the joint become hard and brittle. In silver soldering, a solder composed of equal parts of silver and sheet yellow brass, is generally used, but the more particular manufacturers use pure silver reduced to a powder suited to the gauge of the wire to be soldered. Pure silver will give a softer joint and one of higher conductivity than silver solder. Either electric welding or silver soldering will give a good joint, as was shown by the following test: Four pieces of bare copper ribbon, 0.162x0.250 in., electrically welded, broke at 1066, 997, 1165 and 1085, or an average of 1078 lbs.; four similar pieces, silver soldered, broke at 1258, 988, 1193 and 1267, or an average of 1 177 lbs. The average of four tests on the same section of copper not welded or soldered was 1 350 lbs.

Brush copper is cold rolled and very thin, as it is required to be very flexible and springy. This use and that of sheets for stamping, constitute the largest uses of sheet copper in an electrical works. Stamping copper or "streakless" copper, as it is sometimes called, is subjected to very severe punishment in forming arc lamp parts, various heating utensils, etc., and is required to be dead soft and of unusual ductility.

Commutator bars are hard drawn and are required to be of a uniform degree of hardness and free from slivers and similar defects. The copper used for making switches comes in the form of bars and straps. It also is hard drawn, has a smooth surface and high finish.

ROTARY POWER-FACTOR LIMITATIONS OF CONVERTERS

AS CONTROLLED BY TAP COIL HEATING

J. L. McK. YARDLEY

THE variation in the currents flowing in the different parts of the armature winding of a rotary converter does not seem to be generally realized by operating men. The manner in which the copper loss per coil about the armature circumference varies with the position of the coil with relation to the taps to the collector rings, is shown by the curves in Fig. 1. A study of these curves will explain why it is that careless or indifferent operation of converters without reference to power-factor conditions has sometimes resulted in roasting out armature coils.

The standard temperature rise guarantees at the present time for rotary converters are 35 degrees C. for continuous full load at 100 percent power factor, and 55 degrees C. for two hours, 50 percent overload at 100 percent power factor, for all parts except the commutator, and for that five degrees C. higher. These guarantees are based on an air temperature of 25 degrees and corrections for differences therefrom are made in accordance with the rules of the American Institute of Electrical Engineers. After the converters are installed, however, they are in the hands of operators who are interested not so much in the guarantees as they are in their safe operating limits under the conditions of varying load and power factor existing in the stations where they are installed.

The curves in Fig. 1 show the copper or I^2R losses in the various parts of a given armature winding when operated under the different conditions shown. It is evident from these curves that the loss in the tap coil of a six--phase converter is approximately 50 percent greater at 97.5 percent power factor than at 100 percent power factor; and that at 95 percent power factor it is 80 percent greater. The average I^2R loss at full load, 85 percent power factor, is the same as that at 50 percent overload, 100 percent power factor. The maximum or tap coil I^2R loss is the same at 90 percent power factor full load as at 100 percent power factor 50 percent overload. Operators who would hesitate to run a machine at 85 percent, or even 90 percent power factor full load, do not always appreciate the greater seriousness of running at a few percent off on power factor at 50 percent overload for periods of time approaching the 50 percent overload rating of the converter.

The criterion of permissible I^2R loss in a conductor is the "surface per watt expended" under its particular conditions of ventilation. Sufficient area must be provided that the heat may be dissipated without the temperature of the conductor exceeding the allowed value.

Let N = the number of conductors per slot.
A = the cross-sectional area of a conductor in square inches.
S* = the square inches of surface of one inch length of conductor.
I = the current per conductor (which for a multiple winding may be obtained by dividing the direct-current terminal current by the number of poles).
C = Conductivity of copper at 25 degrees C. = 1.45×10^6.
X = A constant showing the relation between the heating of the top coil operating in the rotary converter at any given power-factor to its heating in the direct-current generator with the same load.
S ÷ W = Square inches of surface per watt expended.

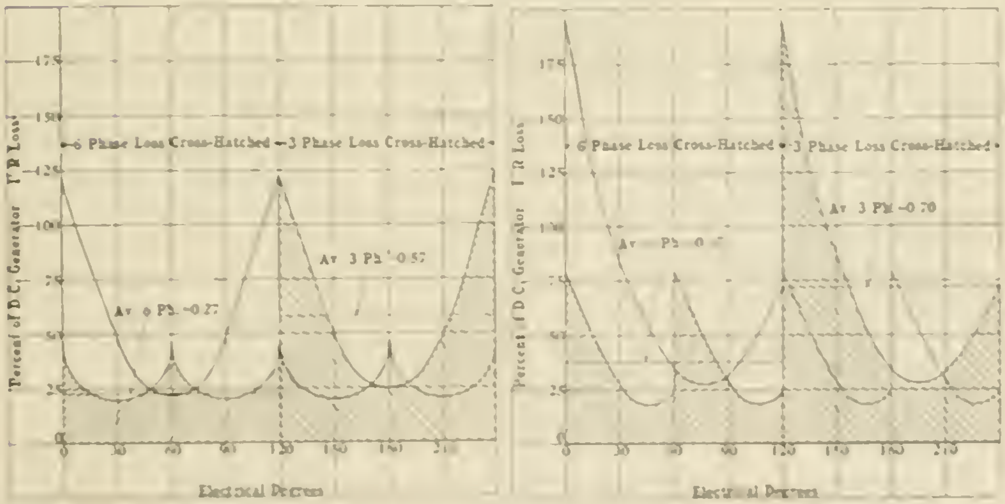

FIG. 1—DISTRIBUTION OF ARMATURE COPPER LOSS IN THREE AND SIX-PHASE ROTARY CONVERTERS

Development of two-thirds of the double pole pitch of the armature winding. The diagram at the left shows conditions with unity power-factor; that at the right, with 95 percent power-factor.

Then $CSA \div NI^2 = S \div W$ in the machine operating as a direct current generator under normal conditions; and $XCSA \div NI^2 = S \div W$ in the machine operating as a rotary converter. The constant X may be taken from the curve, Fig. 3, which is derived from the curves of Fig. 2 as follows:—

The expression $CSA \div NI^2$ is taken as unity in the ordinates of the curves in Fig. 2 and is represented by the horizontal line.

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*N, A and S can usually be determined by examining the winding where it enters the commutator necks.

curve *XI*. Then for a point on any other curve, Fig. 2, the ordinate is the ratio of the heating, under the conditions represented by the abscissa of that point, to the constant heating as a direct-current generator represented by curve *XI*. As the surface per watt expended for a given surface is inversely proportional to the wattage expended, $S \div W$ for any point on a curve in Fig. 2 as compared to $S \div W$ for the machine operating as a direct current generator, curve *XI*, is inversely as the ordinate of the point. Therefore, *X*, the coefficient of $CSA \div NI^2$ is the reciprocal of the ordinate at the point selected. The curve of values *X* in Fig. 3 is derived in this manner from curve *VII* in Fig. 2 for a six-phase rotary converter.

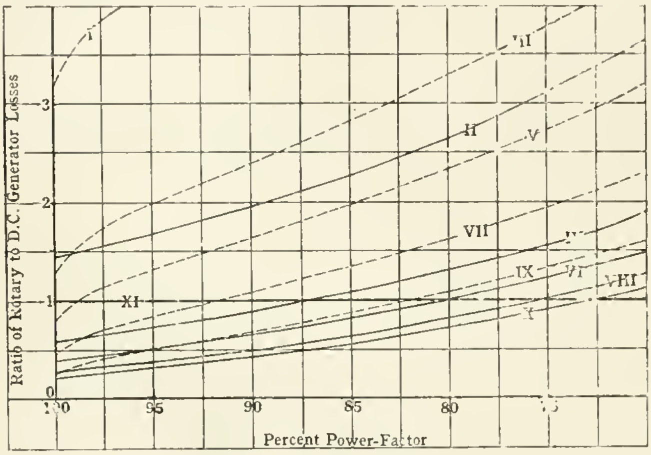

FIG. 2—HEATING OF THE ARMATURE OF A ROTARY CONVERTER AS COMPARED WITH THE SAME MACHINE OPERATING AS A DIRECT CURRENT GENERATOR

Solid lines represent average heating and dotted lines that of the tap coils.

I—2 rings.
II—2 rings.
III—3 rings.
IV—3 rings.
V—4 rings.
VI—4 rings.
VII— 6 rings.
VIII— 6 rings.
IX—12 rings.
X—12 rings.
XI—direct current.

It has been found from experience that the ratio, $S \div W$, as calculated by this formula for a six-phase converter of modern construction must be greater than 0.3 to prevent damage to insulation. This construction has four conductors per slot and two conductors per coil. The insulation inside of the slot consists of 2.5 turns of fish paper and mica, and outside of the slot one turn of cotton tape per conductor and one turn of cotton tape per coil. The core has a vent duct every 2 to 2.5 inches width. The winding has 1/16 to 3/32 inch vents between coils outside the core, the coils being of diamond shape. The peripheral velocity varies from 5 900 to 6 800 feet per minute, and the spider is designed to give the greatest possible ventilation to core and coils.

Although the tap coils have the greatest I^2R loss and therefore the greatest heat generated in them under all conditions of load and at all power factors, it does not follow that the insulation on these coils will be the first to show signs of roasting when the ratio, $S \div W$, is too small. The tap coil has a better opportunity to get rid of its heat than the other armature coils. Some of this heat may pass out through the tap connection, or it may pass into the coils on either side of it when the conditions are such that the heat generated in the coils on either side is decidedly less than that generated in the tap coil itself. Such a condition exists at low power-factor operation. As the power factor departs from unity, the coil on one side of the tap coil has more heat generated in it, and the coil on the other side of the tap coil has less heat generated in it than at unity power factor. This is shown at 95 percent power factor in Fig. 1. There is an opportunity, therefore, for the heat to flow from the tap coil to the coil which is having less heat generated in it. The direction of this flow of heat will depend upon whether the power factor is leading or lagging. In the case of a leading power factor and clockwise rotation of armature, the heat will flow counter clockwise, facing the commutator. If the tap coil be *A* and the next coils in clockwise direction *B* and *C* and the adjacent coil in the counter clockwise direction be *X*, the heat will flow from *A* to *X*; and if the power factor is low enough it is possible that *X* may be the coil which has the least heat generated in it of any in the armature, while *A* is the coil which has the most heat generated in it of any in the armature. As the coil *B* is between the coils *A* and *C*, that is, between the coil which has the maximum amount of heat generated in it and another coil having almost as great a heat generated in it, it cannot radiate its own heat. This explanation accounts for the fact that occasionally the insulation of the coil or coils at one side of the tap coil are injured by low power-factor operation, while the insulation on the tap coil itself is intact. Had the power factor been a lagging one the coil *X* in the above discussion would have shown the burned insulation.

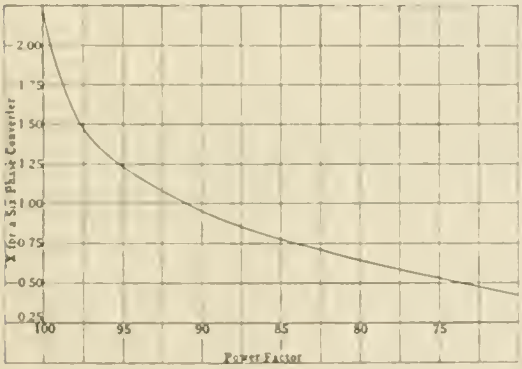

FIG. 3—VARIATION COEFFICIENT "X" FOR A SIX-PHASE CONVERTER

Taking the value 0.3 as a basis, it is possible by means of this formula to derive a curve between power factor and kilowatt output showing the danger limit which must at all times be avoided in operating apparatus of this class. This point will not be discussed further, however, than to call attention to the power-factor curves given by Mr. Jens Bache-Wiig.* These curves show approxi-

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See the JOURNAL for November, 1910, pp. 866-869.

mately the variations in power-factor which occur in securing commercial compounding. The writer merely desires to point out the desirability of adjusting a rotary converter to give 100 percent power-factor at full load rather than at half load. He further desires to commend the present practice of securing the desired compounding by using moderate amounts of both series field and reactance rather than by using a greater amount of series field and a smaller amount of reactance. These two points are of particular importance in connection with rotary converters carrying heavy momentary overloads of 100 or 200 percent, where the effect of the wattless component introduced by the series field ampere-turns upon the tap coil temperature must be seriously considered.

POWER-FACTOR METERS FOR INDIVIDUAL GENERATORS

NICHOLAS STAHL

ANALYSIS of the conditions obtaining in many power houses brings out the fact that the generator windings are often carrying heavy currents, not only when the power factor at the station bus-bars is low, but when it is relatively high, due to the cross currents between the individual alternators operating in parallel. While the voltage of individual machines operating separately is dependent upon the field excitation, when a group of alternators is connected in parallel through one set of bus-bars, their voltage must necessarily be the same. If the field excitations are such that they tend to have unequal voltages, circulating currents flow through the windings in such a manner as to boost or reduce the voltages generated in the different machines to a common value.

It is important to realize that two or more machines operating in parallel will have power factors different, not only from each other, but from that of the bus-bars, unless the proper excitations are obtained, irrespective of whether the power factor of the bus-bars is lagging, unity or leading; and in any of these three cases difference of power factor between the individual machines indicates that cross currents are circulating between them. The elimination of cross currents by the securing of the same power factor on all machines is, of course, highly desirable, and can generally be brought about by the proper setting of the field rheostat, the operator being guided in his manipulation by the indications of a group of any of the three different switchboard instruments commonly used, namely:—field ammeters, armature ammeters, and power-factor meters.

Field Ammeters—A knowledge of the field excitation required by a given machine to carry a certain current will make it possible to interpret the readings of the field ammeter as showing that greater or less excitation is required in the particular case. Too much dependence should not be placed on these readings, however, for several reasons. In the first place, it is difficult for an operator to carry in his mind the range of excitations required for various loads on machines under given power-factor conditions; again, these excitations vary for the same armature current at different power-factors. It is usual to express the field amperes required in terms of percentage load, or percentage k.v.a. on the machine; and then when it comes to taking into account all of the foregoing possibilities for one machine, with a similarly complex number for all the other machines that may be feeding the bus-bars, it is not strange that with this possibility of correction constantly before the operator, in most cases, he still has cross currents existing.

Armature Ammeters—Considering that the true energy load as delivered by each machine is determined by the setting and position of the governors of the prime movers, and that with a given bus-bar voltage and external power factor, the sum of the currents in the individual machines will equal the currents in the external circuit only when all machines are operating at the same power factor, it is evident that, when this condition does not obtain, the machines may all be brought to the same power factor by reducing the sum of their armature currents to a minimum by proper manipulation of the field rheostats. The difficulty in doing this accurately is evident in the mental calculation required on the part of the operator, especially when the loads are fluctuating, as is frequently the case in central stations. Moreover, the loads may change not only in amount but in power-factor, so that the true minimum to be reached is also fluctuating with the outside conditions.

Power-Factor Meters—With a power--factor meter for each machine there is instant evidence that the machines have or have not circulating currents by the inequality or equality of the power factors indicated. It is obvious, also, that the only manipulation required in this case is to see that all power-factor instruments read alike. In other words, if the separate meters all read alike it is not necessary to inquire what the power factor of the outside circuit is, for it will have just been found.

When the effect of overload due to circulating currents on the maintenance of machines and their depreciation is considered, it seems fair to hold that the very slight additional expense required for the necessary instruments and accessories is entirely justified. Moreover, the capacity of the machines for outside work is increased. For example, suppose the outside power factor is 80 percent lagging, and that the normal capacity of the machine is 1 000 amperes. Assuming that the load remains constant, so that the energy output of the machine is unchanged, and the excitation is varied so that a reading of 60 percent power-factor lagging is obtained, the generator would be carrying 1 300 amperes or 30 percent overload in current. Or, to put it another way, if the machine could safely carry 1 300 amperes and, by a change in excitation, this could be reduced for a given energy output to, say 1 000 amperes, there would be 300 amperes additional capacity in the machine for external load, providing the prime mover was capable of supplying the additional energy.

It is not intended by the foregoing to argue against the installation of field ammeters or armature ammeters, but rather to argue the real advantage of supplementing these by power-factor meters which, with a conscientious operator properly instructed, should be most productive of practical results. In general, it is highly advisable to reduce the number of instruments on a switchboard to a minimum, and it is believed that the installation of a power-factor meter, in connection with a single ammeter arranged with a jack for connecting on the various phases, instead of the three ammeters commonly used, would better meet the needs of the average station operator, and at the same time reduce the number of instruments per machine by one. It would also render indicating wattmeters unnecessary, assuming that individual integrating watthour meters would be used in any event.

SHOP TESTING OF ELECTRICAL APPARATUS - IX

DIRECT-CURRENT RAILWAY MOTORS

RAILWAY MOTORS are designed with the most rugged characteristics in order to withstand the exceptionally severe service which they are called upon to meet. The materials used, the insulation and the assembly details are quite different from the series industrial motors previously discussed. Moreover, their exposed position demands total enclosure with a corresponding change in heat distribution, and they are called upon to operate under widely varying voltages. These differences in operation involve sufficient differences in testing details to warrant separate consideration.

The numerical data presented as typical in this article was obtained from a test of a 600-volt direct-current railway motor having an hourly rating of 50 horse-power at 75 degrees C.

MECHANICAL INSPECTION

Before any tests are started, the brushes should be ground to a good fit, they should slide freely in their holders without being too loose and a proper clearance should be provided between the brushholder and the commutator. The armature must be centered in the field and the bearings running cool with no possibility of the oil getting into the windings.

TABLE I—RESISTANCES.

	Ohms at 16.5 Deg. C.	Ohms at 25 Deg. C.
Armature	0.2644	0.2734
Series Field	0.1738	0.1797
Commutating Field	0.08284	0.08566

Temperature coefficient at 16.5 Degrees C = 1.034

RESISTANCE

Resistances are measured by the bridge method. For permanent record they should be reduced to the standard temperature of 25 degrees C. The resistances of the motor which is used as an example, together with these corrections are given in Table I. In computing efficiency in railway work, it is common practice to correct resistances to a temperature of 75 degrees C. to correspond with the temperature at which railway motors are rated, and the resistances in the efficiency calculations in this article are corrected to this value.

SPEED REGULATION

In taking the speed regulation test, the railway motor is belted or direct-connected to a generator of sufficient capacity to carry safely 150 percent motor load. The generator may be loaded on resistance racks or loaded back and the test is then carried out in exactly the same manner and using the same precautions, as already outlined for industrial series motors.*

FRICTION AND WINDAGE

Upon completion of the speed regulation test the motor is disconnected from the generator and run light as a series motor with reduced terminal voltage. A thorough mechanical inspection should be made to make sure that the motor is operating under normal operating conditions, and a sufficiently long run should be given to insure a constant value of friction load as indicated by a steady ammeter reading for a given speed. The motor should be operating without end thrust, with smooth commutator, properly feeding oil and correct brush tension. Readings of volts, amperes and speed should then be taken at four or five points covering the range of the speed curve, varying the impressed voltage to obtain the desired speeds. Care should be taken at starting to see that the initial impressed voltage is sufficiently low so that the motor will not attain too high a speed.

CORE LOSS

Because of the great voltage range over which railway motors are operated in service, their core losses are ordinarily determined by a method different from that described for industrial series motors. The method here given is not strictly correct, as it gives core loss values corresponding to no-load rather than to load conditions. The inaccuracy of the method is due to the fact that a motor operating under load has an armature reaction effect which cannot readily be corrected for in making a core loss test by this method. However, the method is sufficiently accurate for all ordinary purposes and, as it facilitates working up the results for the determination of efficiency, which for railway motors is usually given for three values of voltage, it is the most desirable method of making the core loss test.

After the friction and windage test the motor is shut down and connected up for separate excitation. The field is excited with approximately full-load amperes and the motor is started by bringing up the armature voltage. The excitation is then increased to the maximum value, which, for a motor of this type, is usually 200 percent full-load current, and the voltage is held constant at the value at which the test is to be taken. For railway motors core loss is taken at three voltages, covering the range of operation, and in this case, with a maximum rating of 600 volts, these three voltages may be selected at 550, 400 and 250 volts respectively. When the reading of the armature ammeter becomes constant, readings of field amperes, armature volts and amperes and speed are taken at that point. These readings are taken with the same constant armature

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*See the Journal for August, 1913, p. 796.

TABLE II—CORE LOSS, FRICTION AND WINDAGE

Friction and Windage, Brush Friction.

Before Core Loss Test		After Core Loss Test	
Watts	R.P.M.	Watts	R.P.M.
245	220	244	221
630	568	635	568
720	787	720	785
1 098	920	1 098	917
1 305	1 050	1 295	1 062

Core Loss and Friction and Windage at 550 Volts

Armature Volts	Armature Amperes	Watts	Field Amperes	R.P.M.
550	3.4	1 870	125	526
550	3.1	1 705	100	554
550	3.0	1 650	75	596
550	3.1	1 705	50	650
550	3.3	1 815	30	910

Core Loss and Friction and Windage at 400 Volts

400	2.9	1 160	125	378
400	2.8	1 120	100	398
400	2.6	1 040	75	430
400	2.7	1 080	50	490
400	2.95	1 180	30	661

Core Loss and Friction and Windage at 250 Volts

250	2.45	613	125	236
250	2.3	575	100	250
250	2.15	538	75	264
250	2.25	503	50	314
250	2.5	625	30	420

voltage at four or five values of field excitation, covering the range from 200 to 30 percent normal full-load field current, care being taken at the lower values not to exceed the safe speed limit.

This test is carried out for the three values of voltage selected, and the test for friction and windage should be repeated after each. A varying friction load introduces a possibility of error into the core loss test; accordingly if the value of friction and windage obtained before and after the core loss test do not check to a reasonable degree, the test must be repeated until constant conditions of friction are obtained.

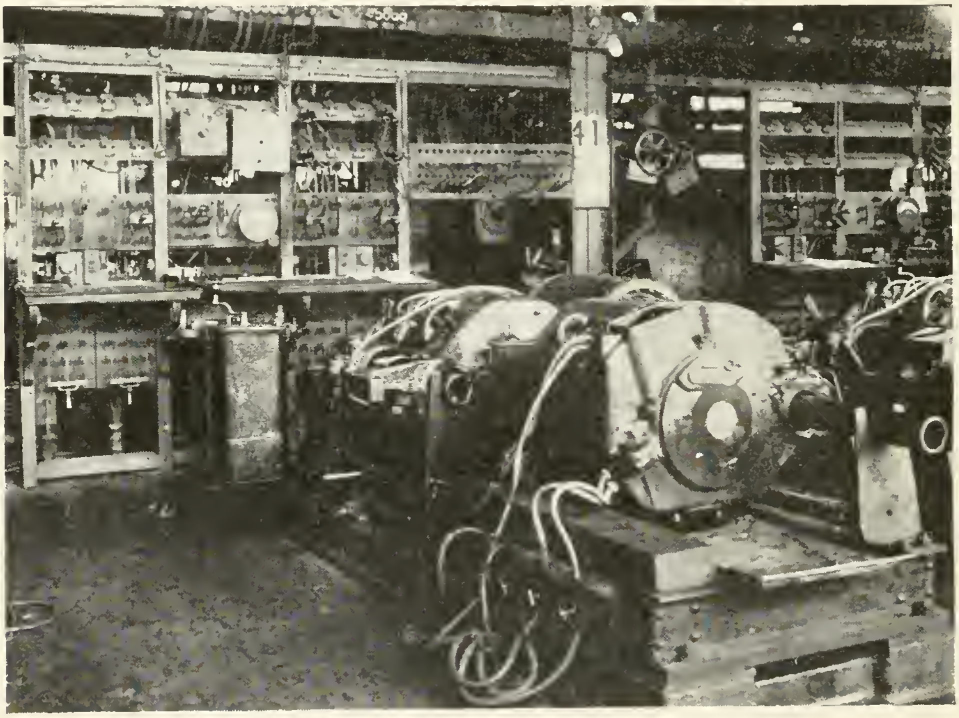

FIG. 1—DIRECT-CURRENT SERIES MOTOR TESTING

Showing method of setting up series motors as motor-generator sets for load tests.

A typical set of friction and windage readings before and after a core loss test, together with the readings for core loss at 550, 400 and 250 volts respectively are given in Table II. The value of watts at each point is obtained as the product of the readings of armature volts and amperes at that point. The corresponding curves as plotted in Fig. 2.

From the curves in Fig. 2 a relation between core loss and armature voltage can be derived directly by separating core loss from friction and windage at a given value of field current for each of the three voltages at which the core loss is taken. Then the resultant curve will be a relation between watts core loss and armature volts for a constant value of field current.

The simplest method of deriving such a relation from the curves in Fig. 2 is to read the values of speed for a given current ordinate on the three current curves; then read the ordinates of the core loss, friction and windage curves corresponding to this speed and subtract from each the ordinates of the friction and windage at the respective points. The result is a set of three core loss readings corresponding to the voltages 250, 400 and 550. These voltages, however, are taken under no load conditions, whereas efficiency is calculated at voltages to be read when the motor is loaded. For this reason, in plotting these relations, the core loss values, instead of being plotted at 250, 400 and 550 volts, are plotted at 250 + I R, 400 + I R and 500 + I R, I in each case being the constant current value corresponding to the points in Fig 2 at which the core loss is taken, and R the total resistance of the motor series circuit. A number of such relations for various constant values of current are plotted in Fig. 3 for use in determining efficiency. Each curve, if continued, should intersect the base line at a value of volts equal to the I R drop at the particular value of amperes for which the curve is being plotted. This drop is given in Table III.

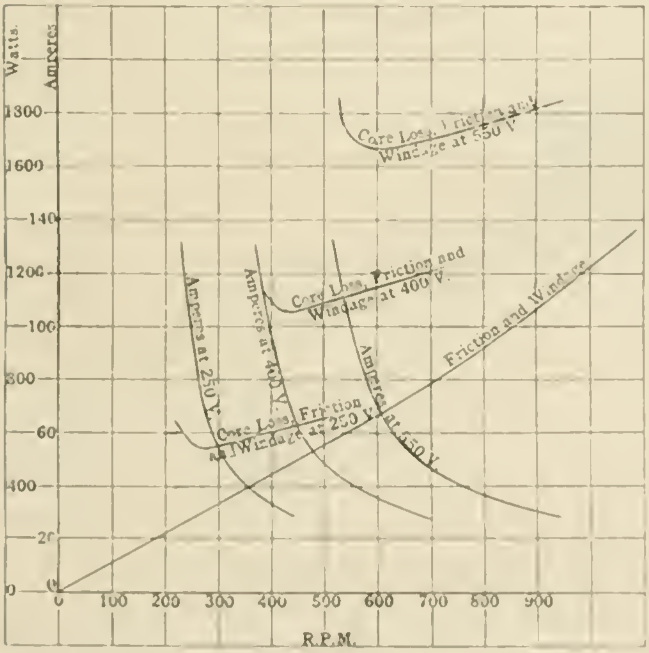

FIG. 2—CURVES SHOWING CORE LOSS, FRICTION AND WINDAGE FOR THREE VALUES OF VOLTAGE

EFFICIENCY

The efficiency of railway motors may be determined in three ways: by separate losses, by brake test and by input-output test of two similar machines. The two latter methods are not very commonly used, but when applied to railway motors are carried out in the same manner as already described for industrial series motors. The first method is the most accurate and at the same time the most expeditious as it utilizes much of the data which must necessarily be obtained in working up other tests.

EFFICIENCY BY LOSSES.

Let E = Terminal volt = rated volts of machine.
I = Terminal amperes at any desired load.
r = Resistance of armature at 75 degrees.
r_1 = Resistance of series field at 75 degrees.
r_2 = Resistance of commutating field at 75 degrees.
*B = Total volts brush drop = $\frac{I}{20 \times \text{total brush area in sq. in.}} + 1$.
R = Armature resistance (r) + series field resistance (r_1) + commutating field resistance r_2.
$e = I \times R$ (total drop of all series windings).
(1) Core loss at terminal voltage *E*, obtained from core loss curve
(2) Copper loss = I^2R.
(3) Friction and windage + brush friction.
(4) Brush loss $I \times B$.
Input = $E \times I$.
Total losses = (1)+(2)+(3)+(4).
Output = Input — Losses.

$$\text{Efficiency} = \frac{\text{Input}}{\text{Output}}$$

$$\text{Horse-power} = \frac{\text{Watts}}{746}$$

$$\text{Torque} = \frac{\text{Hp} \times 5250}{\text{r.p.m.}}$$

	Resistances at 25 degrees.	Resistances at 75 degrees.
Armature	0.2734	0.3262
Series Field	0.1797	0.2144
Commutating Field	0.08566	0.1022
Total		0.6428

TABLE III—PERFORMANCE DATA.

Line amperes	20	30	40	50	75	100	125
R.P.M	1450	1015	835	750	615	552	508
Terminal volts	600	600	600	600	600	600	600
Total drop (e)	12.9	19.3	25.8	32.1	48.1	61.2	80.2
Brush drop	1.4	1.6	1.8	1.9	2.0	2.9	3.3
Core loss	695	780	850	910	980	1030	1080
Copper loss	258	579	1030	1605	3610	6420	10010
Brush loss	28	48	72	95	150	290	412
Friction and windage	1060	670	540	460	360	310	280
Total loss	2041	2077	2492	3100	5100	8050	11782
Watts input	12000	18000	24000	30000	45000	60000	7 000
Watts output	9960	15923	21508	26900	39900	51950	63218
Efficiency	83	88.5	89.5	89.6	88.7	86.5	84.3
Brake hp	13.4	21.4	28.8	36	53.4	69.5	84.6
Torque	48.5	111	181	256	455	661	875

From the curves in Figs. 2 and 3 and the relations given above, a complete table of performance data can be compiled establishing the efficiency at any desired series of loads. Such a table for the motor used as an example is given in Table III and the resultant curves of brake horse-power, torque, speed and efficiency as compared to load are plotted in Fig. 4.

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*The brush drop may also be taken from standard curves compiled from tests on the particular type of brush used.

TEMPERATURE TESTS

There are two common temperature tests for railway motors, one an hour run at the one hour rating, with the commutator covers off with readings every fifteen minutes and the other, a continuous run with commutator covers on at a voltage in the neighborhood of two-thirds normal rating with readings every hour. Of the two the former is the more common, the latter being used for the most part in the experimental testing of new motors. The readings taken in each case are line volts, line amperes, series field volts, commutating field volts and speed, particular attention being paid to commutation. Hot resistances of series field, commutating field and armature are read immediately upon shutting down in the order named, and temperatures are taken by thermometer on the commutator outside edge, middle and groove, field left and right, armature band, armature core, frame and bearings. All these readings should be taken with greatest possible dispatch because of the rapid cooling after shutting down. To facilitate this, warm waste, thermometers and resistance measuring apparatus should all be on hand before stopping the machine.

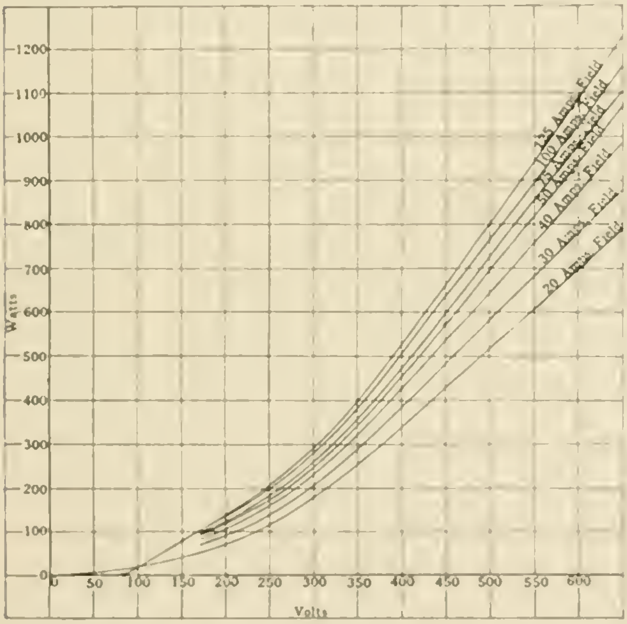

FIG. 3—CONSTANT CURRENT CURVES SHOWING RELATIONS BETWEEN WATTS CORE LOSS AND MOTOR VOLTAGE

FIELD FORMS

A simple and expeditious method of taking field form is effected by means of a fiber template about an inch wide by a sixteenth inch thick, and a little longer than the distance between adjacent brush arms. Holes large enough to accommodate brushes made of pencil lead are drilled along the template a distance apart equal to the combined widths of a copper and a mica segment.

The fibre is then fastened to the brush rigging in such a manner as to fit over the commutator so that the centre of the left hand brush comes midway between two holes and this space is marked, the spaces to the right hand brush and seven or eight spaces back of the left hand brush being numbered consecutively. The template brushes are made by connecting lamp cord to the leads of two hard pencils whose lower ends are so sharpened that they will extend through the holes in the template and rub on the commutator. Because of the very small size of these brushes, this test should be taken only with a very well polished commutator, as they will otherwise wear away too rapidly. The test brushes are connected to the terminals of a low reading voltmeter and when arrangements have been made to keep constant voltage and current on the motor, it is started for the test.

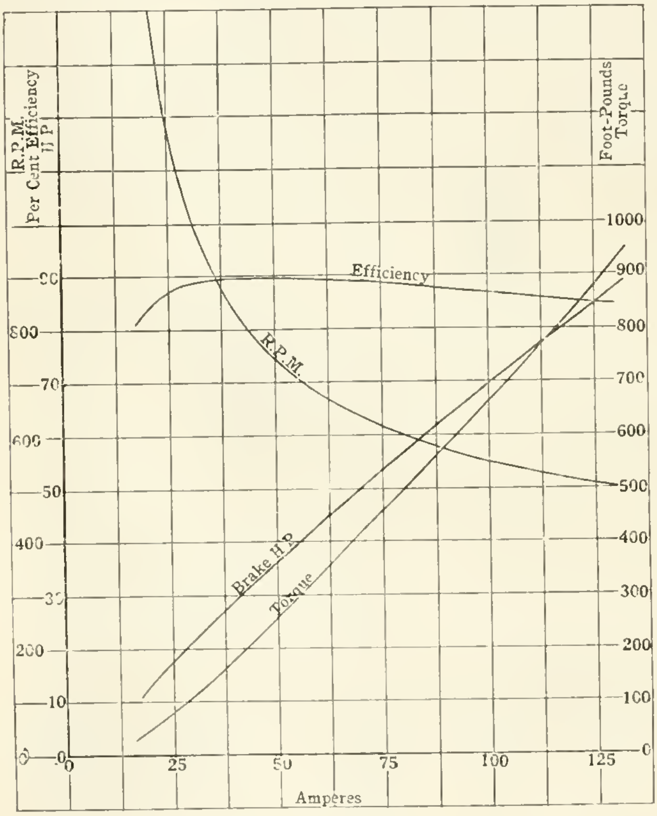

FIG. 4—PERFORMANCE CURVES OF A DIRECT-CURRENT RAILWAY MOTOR

The machine is run as a series motor under the desired conditions of load and readings of voltage are taken with the pencil brushes in each pair of adjacent template holes. These readings are then plotted with the space numbers of the template as abscissæ and the voltages across the respective spaces as ordinates. In order that the direction of rotation may be represented in a right-handed direction across the curve sheet in each case, field forms taken for right hand rotation should be plotted with zero point at the left hand side, while those for left hand rotation should have their zero point at the right.

Commutating Field Form—The field form of the commutating field is taken in the same manner as given above, except that the motor is driven by a shunt motor. Leaving the series field out of circuit, the current as obtained from the speed curve corresponding to the speed used is passed through the armature and commutating field in series and voltage readings taken.

NEUTRAL CHECK

To test for correct brush setting the motor should be connected to a similar machine operating as a generator which may be loaded back or carrying a resistance load. If the latter, care should be taken that sufficient load is connected in when starting. The motor is then started slowly and the load brought up to normal. Speeds are checked at the 100 and 125 percent load points for each direction of rotation, readings being taken of line volts, line amperes, field volts and speed in each case and commutation noted. A five percent variation from the limits for which the motors are designed is reasonable for speed and field volts.

HIGH SPEED TESTS

The high speed requirement for a railway motor is usually in the neighborhood of 7 000 feet per minute armature peripheral speed. To run the test the motor is disconnected from its load and started at very low voltage, which is increased until the motor reaches the required speed. While the motor is coming to a stop after this test is an opportunity to polish the commutator with fine sandpaper. The motor should then be connected at once for separate excitation and run at rated voltage to detect any defects which the high speed test might bring out, such as short-circuits, high commutator copper or mica, and coil displacements.

INSULATION TESTS

It is always advisable to take a leakage or insulation resistance test to indicate the condition of the insulation before taking the high voltage alternating--current test. When the first test is satisfactory, as explained under industrial series motors, the high potential test to ground is taken according to the requirements for the particular motor being tested.

COMMERCIAL TESTS

Where railway motors are made in large quantities and of standard design, complete tests need not be frequent and the commercial tests neeed only be such as will fully demonstrate any electrical or mechanical defects or prove the similarity of the machine to standard machines of the same design. A rigid mechanical inspection, as described at the beginning of the article, together with the last three test described above, namely, neutral check, high speed and insulation tests, constitutes ample check for ordinary commercial purposes.

THE JOURNAL QUESTION BOX

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A stamped, self-addressed return envelope should accompany each inquiry. Address all questions to Question Box Department, care THE ELECTRIC JOURNAL, 200 Ninth Street, Pittsburgh, Pa.

952—**Wear of Converter Commutator**—A sub-station contains two rotary converters, three-phase, 25 cycle, four poles, 340 volts alternating current and 500 to 550 volts direct current arranged for shunt or compound running, one for power supply and the other for lighting. There is a single-phase transformer on each phase. There are also two induction motor generators. We are troubled with an uneven wearing of the commutators in grooves. All the armatures have ample end play in the bearings. Sometimes the wear is even and at others very uneven. When it is even wear there seems to be a slight pulsation in the alternating current circuit as the ammeter has a tendency to pulsate and the armature appears to follow this. On the other hand, at times the ammeter needle follows the load with a dead beat action and the armatures run in one position and the result is uneven wear. What is the cause of this and how can I arrange to get even wear on the commutators? The alternator at the power house is three-phase, 25 cycle, 8 pole. The line is about three miles long, two three-core cables running in parallel and all star connected at the power station. H. A. (ENGLAND)

These rotaries apparently have no mechanical oscillators. By equipping them with mechanical oscillators and properly adjusting the amount of oscillation, trouble from uneven commutator wear should be eliminated. The armature movement referred to is assumed to be parallel to the shaft; if this is so, it is proof that an oscillator will improve operation. R. H. N.

953—**Permeability of Laminated Iron**—It is generally recognized that the annealing of laminations in direct current armatures and alternating current stators reduces the core-loss; can you give any general figures for the percentage of such reduction that may be expected in small motors up to 50 horsepower, in the ordinary standard types and sizes; applying to reduction in total losses? It has recently come to my attention that annealing such laminations increases the permeability by a very considerable amount in some densities. Can you give me any data regarding the effect on the permeability? H. W. S. (OHIO)

The percentage gain due to annealing punchings for motors depends entirely upon the previous history and annealing of the sheet steel at the rolling mill. Steel which has not been annealed at all will generally have its losses reduced 50 percent by annealing. Most steel used for magnetic purposes is annealed by the makers and subsequent annealing may or may not affect the losses very much. Five to twenty percent is the usual decrease in loss, due to careful annealing. The losses in the motor will be reduced but one or two percent by this change. Annealing improves the permeability on moderate and low inductions, but has little effect at high induction. L. W. C.

954—**Underwriter's Approval**—Please explain the requirements to get electrical apparatus approved by the Board of Underwriters. Can apparatus be sold pending approval by the Underwriters? M. F. C. (IDAHO)

Apparatus to be approved under the provisions of the National Electrical Code must be submitted to the Underwriters' Laboratories, Inc., either at Chicago or New York. The Underwriters send representatives to manufacturing plants when so desired, or the apparatus under consideration may be sent to Laboratories where it will be tested with reference to its meeting the requirements of the National Electrical Code and with reference to its performance, judged from the fire hazard standpoint. The results of the tests and examinations by the Laboratories are put into the form of a report which is submitted to the Electrical Committee of the National Fire Protection Association and this committee votes to approve or disapprove the recommendations of the Laboratories. The final decision of the committee is promulgated in the form of a card which is furnished to all inspection departments throughout the United States, and these inspection departments in examination of risks will, in practically all cases, follow the findings of the Electrical Committee. If a device is judged as satisfactory by the Laboratories and the committee, it will be passed by an inspector; if judged as unsatisfactory and as not meeting the requirements of the Code, the approval of the risk may be withheld until such device is removed or modified in accordance with the suggestions of the Laboratories. The Underwriters' Laboratories and the National Fire Protection Association have no authority to prohibit the manufacture and sale of such devices as are not approved or prohibit their sale pending approval. They cannot prohibit their installation, except by their refusal to insure property where such devices are installed.

C. E. S.

955—Tractive Effort—In a single end, four motor railway car, wired for series parallel operation, which method of connecting the motors will give the greater tractive effort on the series positions. Nos. 1-2 and 3-4 motors in parallel as in Fig. 955 (a) or Nos. 1-3 and 2-4 motors in parallel as in Fig 955 (b)? Which method is better practtice and why. C. W. Y. (MO.)

Tractive effort is entirely a function of current, and for a given current in the motors, the same tractive effort is secured with either method of connection. The connections shown in Fig. 955 (b) are standard for K or drum type controllers, the purpose being to keep both trucks active and, therefore, maintain smooth acceleration during the transition from series to parallel, while one pair of motors is momentarily short-circuited. This arrangement is also advantageous when operating a car on short radius curves, with one pair of motors cut out. The two active motors, being located one on each truck, will prevent one truck from binding on the curve and stalling the car. K. A. S.

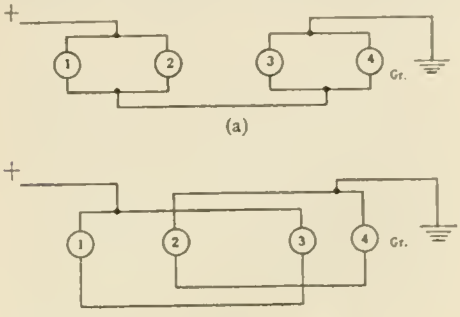


FIG. 955 (a) AND (b)

956—Polyphase Wattmeter with Unbalanced Load—A five horsepower, 220 volt, two-phase, 60 cycle motor is metered by a two-phase watt-hour-meter. On one phase of this same meter there is a three horsepower, single-phase, 220 volt motor. Would there be any error in the wattmeter reading as shown, and if so, how much?

E.G. E. (W. VA.)

Within the inherent limits of accuracy of the meter, the registration will be correct. C. R. R.

957—Local Distribution System—We have a three-phase, 550 volt distribution system in a paper mill which at present is being overhauled. Owing to the presence of acid fumes most of the wiring is carried on overhead roof trestles, requiring spans of from 60 to 150 feet. The main cable feeders vary from 400 000 to 750 000 C. M. Such cables, often nine in all, run to a single steel trestle. What type of suspension strain insulator would you use for this voltage or do you think pin type insulators would answer? Would you advise using a suitably large cable clamp? We are not inclined to regard a clamp on such a large cable as satisfactory. To make it easy on the cable we are using large sags. Do you regard this formula satisfactory for calculating pull on strain insulator?

$h = \frac{w\ s^2}{8t}$ where h = sag in feet, w = weight per foot, t = total tension in wire in lbs. at center of span, and s = span in feet. Ice allowance, ½ inch all around.

With these heavy cable spans we are adopting a wound and soldered type of connector. Would some other form be preferable?

A. S. (ONTARIO)

We consider that a pin type porcelain insulator supported on a bracket would be cheaper than a suspension type of insulator. For dead ending, an adjustable wood strain insulator is suggested. A wound and soldered joint is entirely satisfactory where the feeder is tapped. The formula for sag and tension is correct, except that the allowance for ice coating should be made only for wiring which is exposed to the weather

W. S.

958—Single Phase from Two-Phase—The primaries of two single-phase transformers are connected to the proper lines of a four-wire, two-phase circuit. The secondaries of the transformers are connected in series, as in Fig. 946 (a). What potential exists between the outside secondary leads? Can a single-phase load thus be balanced on a two-phase circuit? If not, why?

C. J. E. (OHIO)

(a) The voltage between the two outside secondary leads is 41.4 percent greater than that across the secondary of one transformer. (b) A single-phase load can be balanced on a two-phase circuit in this manner so far as current is concerned, but the rating of each secondary winding is only 70.7 percent of the single-phase rating. The vector relations of the primary circuit will be disturbed, however, to such an extent that only a single-phase load is taken from the generator. Thus, as shown in Fig. 958 (b), the single-phase line e.m.f. will be the vectorial sum of the two e.m.fs. in the transformer secondaries and will be 45 degrees out of phase with each of the primary e.m.fs. The secondary current will, with a lamp load, be in phase with the secondary e.m.f. The primary current must, of necessity, except for the effect of magnetic leakage in the transformers, be exactly opposite that in the secondary. Hence ,the current in phase *A* will lag its voltage by 45 degrees while that in phase *B* will lead its voltage 45 degrees. In other words, the two currents will be in phase with each other. Hence, only a single-phase current is drawn from the generator, through two circuits in parallel. With a unity power factor in the secondary, the amount of power carried by each phase of the primary will be equal. But at lower secondary (single-phase) power factors, the power in the two primary phases will become more and more unbalanced until, with a single-phase load at 70.7 percent power factor, the power in one of the primary phases will be zero, and the other phase will be carrying all the load, although the current in the two phases will still be approximately equal. At lower single-phase power factor, the power in one primary phase will be reversed. See also article by Mr. C. F. Scott on "Three-Phase vs. Single-Phase Transformation" in the JOURNAL for January, 1906, page 43.

W. M. M.

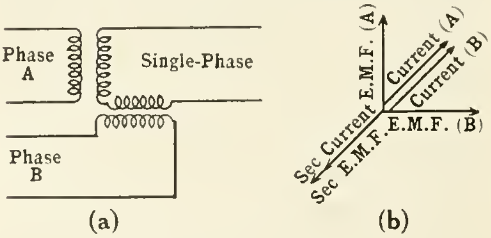
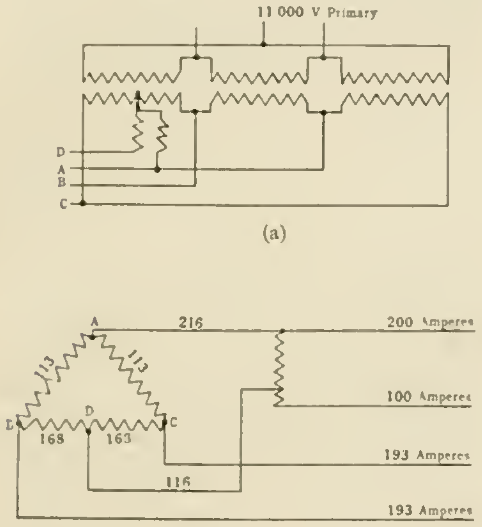


FIG. 958 (a) AND (b)

959—Two-Phase Three-Phase Transformer Connections—With the scheme of connections for a bank of 11 000 volt to 2 300 volt transformers shown in Fig. 959 (a), for supplying a two-phase motor load from *AD* and *BC* and a three-phase motor load from A-B-C, the transformer which has a middle tap on the secondary was found to be carrying considerable more current than the other two. Should the load distribute itself equally on the three units with this connection when the two-phase and three-phase loads are balanced as with induction motors? What will happen in case of unbalanced loads on either the two-phase or three-phase terminals? G. H. H. (CALIF.)

The load should not distribute itself equally in the case illustrated, but the transformer having the middle tap on the secondary would have a much larger load than the other two with balanced loads on both three-phase and two-phase. The three-phase load would be balanced on the three transformers under all circumstances, so that it is only the two-phase load which causes the overheating of this transformer. The currents in the transformer and in the line, with a balanced load of 100 amperes, three-phase, and 100 amperes, two-phase at unity power factor of load are shown in Fig. 959 (b). The current in phases AB and AC $= \sqrt{(58 + 58 \cos 30^\circ)^2 + (58 \sin 30^\circ)^2}$; the current in phases BD and DC $= \sqrt{(100 + 58)^2 + 58^2}$; and the surrent in the lines B and C $= \sqrt{(100+58+58 \cos 60^\circ)^2+(58 \sin 60^\circ)^2}$. By the method indicated in the above equations the effect of any unbalance of load at any power factor may readily be determined. C. F.



(a)

(b)

FIG. 959 (a) AND (b)

960—Unbalanced Scott Connection—(a) Two standard 2 200 to 220 volt transformers are connected on the high tension side like the Scott connection except that no 87 percent tap could be found and the full 100 percent winding is used. Is this called a "T" connection? If the two-phase, 220 volt circuit be connected to the low tension side what will be the phase relations and voltages on the high tension side? Also please show by vector diagrams what will be the phase and voltage relations on the low tension side if a three-phase, 2 200 volt potential be connected to the high tension side (b). A 90 percent tap on the high tension side of one of two 13 200 to 2 200 volt transformers is used instead of an 87 percent tap to transform from three to two phases. What will be the effect on the low tension side? Can you give any reason why the transformer, with the 50 percent tap should heat up? The heating is not due to the load for other standard transformers of the same capacity with the true Scott connection handled this load without heating. C. W. F. (OHIO)

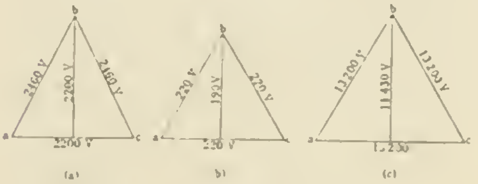


FIG. 960 (a), (b) AND (c)

(a) A "T" connection is used only for three-phase transformation with both high tension and low tension connected in the same manner. If 220 volt, 2 phase be applied to the low tension, the phase relations and voltages of the high tension will be as shown in Fig. 960 (a). There will be 2 200 volts induced across the high tension winding of each transformer and the cross voltage *ab* and *bc* will be $\sqrt{2\,200^2 + 1\,100^2} = 2\,460$ volts. If balanced three-phase voltage be applied to the high tension, the voltage across the low tension of the main transformer will be 220 volts, while that across the teaser will be $\sqrt{220^2 - 110^2} = 190$ volts, as shown in Fig. 960 (b). (b) Referring to Fig. 960 (c) it will be seen that the proper voltage for the teaser transformer is 11 430. The tap used is for $0.9 \times 13\,200 = 11\,880$ volts. 11 430 volts are, therefore, being applied to a winding intended for 11 880 volts and the voltage across the low tension is $\frac{11\,430}{11\,880} \times 2\,200 = 2\,116$ volts. The voltage across the main transformer is 2 200. We have then one low tension voltage approximately 3.5 percent higher than the other, which tends to make the main transformer take the greater share of the load. This may explain the heating referred to, although there may be additional causes. See Nine-Year Topical for references to numerous articles on this subject. W. M. M.

961—Parallel Operation of Rotary Converters—(a)—Given two single-phase rotary converters on the same shaft designed to operate in parallel upon 400 volts direct-current. If the poles, armatures and alternatingcurrent taps of both machines are in the correct relative positions, does the direct-current brush position have anything to do with the correct paralleling of the alternating-current ends? When these machines are connected in parallel sixteeen amperes flow through them, and there is something like forty-six volts between alternating-current rings that should be zero. (b)—Assuming the machines to be correctly assembled, what might be the trouble? W. W. B., JR. (PENNA.)

(a)—Yes. (b)—The circulating current may be due to difference of brush position or to difference of field excitation, or to differences in field flux distribution due to different magnetic constructions in the machines. J. L. Y.

962—Effect of Change of Frequency —(a)—Assume that we have two 1.5 horse-power, three-phase, 220 volt induction motors, one being for 60 cycle and the other for 25 cycles. What difference would there be between the two machines? (b)—If these machines were wound for 220-440 volts, what changes in the windings would be necessary if machines were to run on 500 volts or 650 volts. I am not after specific information regarding certain motors, but am somewhat hazy on the principles involved. R. B. (CONN.)

(a)—We assume that the speed of the two machines should be as near as possible the same. In this case the two machines must be wound for different number of poles, as per example:

For 60 cycles, $\frac{7\,200 \text{ alternations}}{6 \text{ poles}} = 1\,200$ r.p.m. synchronous speed.

For 25 cycles, $\frac{3\,000 \text{ alternations}}{2 \text{ poles}} = 1\,500$ r.p.m. synchronous speed.

In order to obtain similar performance in both machines it is necessary to use the same number of slots per phase per pole and, therefore, we will have in the first case,

6 poles × 3 phase × 2 slots per pole per phase (at least) = 36 slots (minimum).

2 poles × 3 phase × 2 slots per pole per phase (at least) = 12 slots (minimum.

Therefore, the diameter of the six pole motor should be considerably larger than that of the two pole to accommodate the larger number of slots. On the other hand, the length of core will be greater on the two pole motor. The depth of iron below the slots will also be very much different in the two machines as the flux per pole is, of course, greater on the two pole than on the six pole machines. In general, it can be said that for a given horse-power and speed, the 25 cycle machines have smaller armature diameter and greater length of core. There are, of course, other differences like size of rotor resistance rings, number of turns per coil, etc., but the main difference is in the frame dimensions.

(b)—With regard to the difference between machines of same horse-power, frequency, phases and speed, wound for different voltages, this can be determined very easily by considering that the magnetic flux and total ampere-turns should be the same on a given frame and rating irrespective of the voltage for which the motor is wound. Now, the magnetic flux is equal—

$$\Phi = \frac{\text{Voltage}}{\text{Constant} \times \text{r.p.m.} \times \text{total turns}} \quad (1)$$

Ampere turns = total turns in the motor × amperes per phase at full load .... (2)

From formula (1) it is evident

that an increase in voltage requires an increase in number of turns in direct proportion. Similarly formula (2) shows that for a given horse-power, in order to keep the ampere-turns constant, we need to increase the number of turns when the amperes per terminal decrease, and the amperes decrease in proportion to the increase in voltage. The total number of turns is equal to the turns per coil multiplied by the number of coils, and the number of coils equals the number of slots for a two coil per slot winding, and equals one-half the number of slots for a one coil per slot winding.

It follows that the number of conductors per slot varies in proportion to the voltage. The section of each conductor, on the contrary, varies in inverse proportion. For example, in a 1.5 horse-power, three-phase, 440 volt motor, having one coil per slot and 65 conductors per slot, the cross-section of conductor is 0.00063 sq. in. In a 1.5 horse-power, two-phase, 550 volt motor, having one coil per slot and 65 conductors per slot, the cross-section of conductor is 0.00050 sq. in. It will be seen that the ratio $\frac{440}{550} = \frac{65}{79} = \frac{0.00050}{0.00063}$ is approximately correct. G. P.

963—Cost of Operating Motors:—Please advise how to figure the cost of operating a motor, either alternating or direct-current, for any size in horse-power at any rate for power. A. F. L. (PENNA.)

In order to figure the cost of operating a motor, it is necessary to know the efficiency of the motor, then the input of motor will be

$$\frac{\text{Hp developed} \times 0.746}{\text{efficiency}} = \text{kw input.}$$

If now the rate at which power is sold is known, the cost of operating the motor per hour will be—Rate (dollars per kw-hr.) × kw input = dollars per hour. She article on "Estimating Power Costs" in the JOURNAL for February, 1911. G. P.

964—Care of Storage Batteries:—A storage battery equipment was to be put out of commission for an indefinite time and its owner did not wish to spend any money or care on it during that time. In looking after this work I followed carefully the directions prescribed in American books such as "Fosters Hand Book," "Franklin and Esty," "American School of Correspondence," and others; the battery, discharged in rain water until the voltage came practically to zero, was rinsed with several changes of water and afterwards the plates were allowed to dry. This American practice was impugned here and I wish to have your opinion as to the efficiency of such a procedure as recommended by American authors and if you know of any American firms who use this method of putting their batteries out of service. A. A. T. (ENGLAND)

The method outlined for taking a storage battery of the stationary type out of commission will give good results, but it has been found that the process can be very much simplified and equally good results obtained by omitting the discharge in water, and instead, allowing the elements to stand immersed in water for 12 or 15 hours, after which the water can be withdrawn and the plates can then stand indefinitely without further attention. We take it that you have in mind storage batteries for stationary service. For batteries for vehicle service, the taking out of commission procedure is somewhat different and the above comments will not apply. H. L.

965—Exciter Operation:—Please tell (a) how to determine what size the exciter should be for a given size of alternator; also, the amount of resistance necessary to insert in the field circuit of an alternator of given size. (b) Please describe the best method of applying a test load on a 220 volt, 60 cycle alternator of a given size? A. F. L. (PENNA.)

(a) The ampere capacity of the exciter should be equal to the exciting voltage (usually 125) divided by the resistance of the field winding of the alternator. The resistance of the alternator rheostat should be sufficient to reduce the alternator voltage to 70 percent of normal with normal exciter voltage. (b) If the alternator is connected to its engine it may be loaded on water rheostats. Barrels may be conveniently used for a temporary rheostat. F. D. N.

966—Synchronous Motors with Alternating Excitation:—A 60 cycle motor, to operate at synchronous speed of 100 r.p.m. must have 72 poles. Would it be possible to excite the wound secondary of an induction motor, or the field of a synchronous motor with 30 cycle current, so that a 36 pole motor would operate at 100 r.p.m. and thereby affect a saving in the cost of the motor. Would the size of the exciter have to be great enough to over balance this saving? (b) Would it be possible to generate 60 cycle current in a 36 pole generator at 100 r.p.m. in a similar manner by exciting the fields with 30 cycle current? Would any current in this case be drawn from the exciter by a sort of transformer action in the generator in addition to that required to excite the generator field? Please explain why this scheme is or is not practicable?

R. B. (PENNA.)

If a synchronous motor is provided with a distributed field winding having the same number of phases as the armature winding and excited with polyphase alternating current, the motor will rotate at such a speed that the sum of the exciting frequency and the frequency due to rotation is equal to the armature supply frequency. Thus, if the armature frequency is 60 cycles and the exciter frequency is 30 cycles, the frequency due to rotation will be 30 cycles and the speed with 36 poles will be 100 r.p.m. This, of course, assumes that the exciter windig is so connected that the exciting field rotates in the same direction, as the field rotates mechanically. The motor would operate as a generator, as in the case with any synchronous motor. With the speed and pole combination assumed, the exciter would supply half the energy to the 60 cycle circuit through transformer action in the machine operating as a generator, the other half being supplied through transformation of the mechanical energy of the prime mover. This means the exciter would be half the capacity of the main generator. It will be noted that structurally the synchronous motor would be the same as a phase wound induction motor and an induction motor so excited would probably operate in synchronism as a synchronous motor at low loads. At larger loads, it would pull out of step and operate as an induction motor. The difference between the synchronous and induction motors would, therefore, be only in the design proportions, the synchronous motor being designed with a sufficiently strong field with respect to the armature that it would not pull out of synchronism under the loads for which it is designed. While this method of excitation is feasible, the cost of the motors and alternating-current exciters would not compare favorably with the cost of the ordinary forms of motor with double the number of poles. This is particularly true in the case of the synchronous motor since doubling the number of poles with constant speed reduces the cost rather than increases it.

F. D. N.

CORRECTIONS

The first paragraph under the heading "Commercial Test," p. 804 of the August JOURNAL, should read as follows:

The ball bearing should be examined to see that proper lubricant has been supplied in sufficient quantity. The brush holders should be set for backward lead, with the direction of rotation such as to give forward movement of the vehicle. The motor is then belted or direct connected to a generator of sufficient capacity to furnish 200 percent motor load. The field windings are usually divided into two circuits, which may be connected in series or parallel. During the test, these circuits are ordinarily connected permanently in parallel.

In the sixth line from top of p. 753 in the August JOURNAL, the word "inversely" should read "directly." In the caption to Fig. 9, p. 759, the word "grounded" should read "ungrounded."

PERSONALS

Mr. J. Franklin Meyer, Ph.D., for the last four years physical engineer for the Westinghouse Lamp Company, Bloomfield, N. J., has been appointed associate physicist in the Bureau of Standards, Washington, D. C. Dr. Meyer entered on his new work on July 16.

Prof. Henry H. Norris, head of the department of electrical engineering at Cornell University, has resigned, but will continue to have his headquarters in Ithaca, N. Y., where he will devote part of his time to editorial work. Prof. V. Karapetoff has been appointed acting head of the department of electrical engineering. At present Prof. Karapetoff is on a long western tour of inspection of various power and transmission systems.

Mr. C. H. Sanderson, general engineer on switchboard and power station design for the Westinghouse Electric & Mfg. Company, has resigned to accept the position of electrical engineer of the Havana Electric Railway Light & Power Company. On August 13 a farewell dinner was given in honor of Mr. Sanderson at the Fort Pitt Hotel by about 75 of his associates, at which he was presented with a handsome watch fob.

Mr. G. W. Canney, manager of the service department of the Westinghouse Electric & Mfg. Company, is touring the West on an inspection trip.

ILLUMINATING ENGINEERING SOCIETY CONVENTION

At the last meeting of the General Convention Committee of the Illuminating Engineering Society, held in the rooms of the society in the Engineering Societies' Building, New York City, complete arrangements were made for the seventh annual convention to be held at Hotel Schenley, Pittsburgh, September 22 and 26. The Attendance and Transportation Committee reported that such a large number of members and others interested in illumination had signified their intention of being present at the convention, that the attendance will probably far surpass all previous conventions. The committee has arranged for a pecial train to leave New York over the Pennsylvania Railroad, Sunday, September 21, at 10 A. M. The delegates from Boston will also travel by this train. It will pick up a delegation in Philadelphia at 11:57 A.M., and reaching Harrisburg at 2:35 P. M., will there take on the delegates from Baltimore and Washington, reaching Pittsburgh at 8:50 P. M. A special train for the Western delegate will leave Chicago over the Lake Shore & Michigan Southern Railroad from the La Salle Street Station at 8:20 P. M., Sunday, September 21, arriving at Pittsburgh at 7:40 A. M., Monday. Other special accommodations will be provided as needed. These trains will be met at points outside of Pittsburgh by members of the local committee to look after the needs of the travelers.

The local committee has arranged for a full program of entertainment features, including baseball, golf, tennis, theatre and bridge parties, trips to some of Pittsburgh's big industrial plants, automobile rides, ending in a banquet on Wednesday evening, September 24.

A glance at the program given below will give an idea of the good things offered by the Papers' Committee. The meeting Tuesday evening will be held in Soldiers' Memorial Hall, at which time a description and demonstration of the wonderful lighting effects installed therein will be given. The Publicity Committee is preparing an attractive souvenir book containing a program of the convention, a copy of which will be mailed to each member, and any others desiring it, about a week before the convention.

The following program of papers has been decided upon:

"The Development of Alternating-Current Luminous Arc Lamps," Dr. C. P. Steinmetz, of the General Electric Company, Schenectady, N. Y.; "The Quartz Mercury Vapor Lamp and its Application," Mr. W. A. D. Evans, Cooper, Hewitt Electric Company, Hoboken, N. J.; "Characteristics of Enclosing Glassware," Mr. V. R. Lansingh, of the Holophane Company, Cleveland, Ohio; "The Cooling Effect of Leading In Wires Upon the Filaments of Lamps of the Street Series Type," Mr T. H. Amrine, of the Harrison Laboratory of the General Electric Company; "The Neon Tube Lamp," Mr. M. Georges Clause, of Boulogne, France; "The Pentane Lamp as a Working Standard," Messrs. E. C. Crittenden and A. H. Taylor, of the Bureau of Standards; "The Use of Nitrogen at Low Pressure in Tungsten Lamps," Mr G. M. J. MacKay, of the Research Laboratory of the General Electric Company, Schenectady.

N. Y.; "The Photo-Electric Cell in Photometry," Prof. F. K. Richtmyer, of Cornell University, Ithaca, N. Y.; "The Efficiency of the Eye Under Different Systems of Illumination. The Effect of Varying the Distribution and Intensity of Light," Dr. C. E. Ferres, of Bryn Mawr College, Bryn Mawr, Pa.; "Some Theoretical Considerations of Light Production," Mr. W. A. Darrah, of the Westinghouse Electric & Mfg. Company; "Errors in Photometric Measuremeents," a paper by the Engineering Department of the National Electric Lamp Association, Cleveland, Ohio; "The Illuminating Engineering Laboratory of the General Electric Company at Schenectady," Mr. S. L. E. Rose, General Electric Company, Schenectady, N. Y.; "Church Lighting," Mr. R. B. Ely, of the Philadelphia Electric Company, Philadelphia, Pa.; "Modern Practice in Street Railway Illumination," Mr. S. G. Hibben, of the Macbeth-Evans Glass Company, Pittsburgh, Pa.; "Hospital Lighting," Mr. W. S. Kilmer, of the H. W. Johns-Manville Company; "Window Lighting," Mr. H. B. Wheeler, of the National X-Ray Reflector Company, Chicago, Ill.; "Distinctive Store Lighting," Mr. C. L. Law, superintendent of the Bureau of Illumination, New York Edison Company, and Mr. A. L. Powell, of the Harrison Lamp Works of the General Electric Company; "Some Commercial Aspects of Gas Lighting," Mr. J. E. Philbrick, of York, Pa.; "A Problem in Church Lighting," Mr. E. F. Kingsbury, of the Photometrical Laboratory of the United States Improvement Company, Philadelphia, Pa.; "New Commercial Fields Opened by Recent Developments in Lamp Manufacture," by the Engineering Department of the National Electric Lamp Association, Cleveland, Ohio; "The Evolution of Illuminants," Mr. Roscoe E. Scott, of the National Electric Lamp Association, Cleveland, Ohio; "The Psychological Values of Light, Shade, Form and Color," Dr. F. Park Lewis, president of the American Association for the Conservation of Vision, Buffalo, N. Y.

DETAILED PROGRAM.

Monday, 9:00 A. M.—Registration, Session; Address of Welcome, Response, Presentation of Historic Gavel to Society by Prof. Geo. A. Hoadley, of Swarthmore College. Presidential Address, P. S. Millar. Report of Committee on Progress, F. N. Morton, chairman.

Monday, 2:30 P. M.—Technical Session.

Monday, 8:30 P. M.—Reception and Ball for members and friends, in Hotel Schenley Ball Room.

Tuesday, 10:00 A. M.—Technical Session.

Tuesday, 2:00 P. M.—Visit to East Pittsburgh works of Westinghouse Electric & Mfg. Company.

Tuesday, 8:00 P. M.—Lecture at Soldiers' Memorial Hall, "The Evolution of Illumination," Mr. Roscoe Scott, of Cleveland.

Wednesday, 9:30 A. M.—2:00 P. M.—Commercial Session, papers and discussion.

Wednesday, 3:00 P. M.—Forbes Field. Baseball Game. National League, Pittsburgh vs. Brooklyn.

Wednesday, 6:30 P. M.—Banquet at Hotel Schenley.

Thursday, 10:00 A. M.—Technical Session; Papers and Discussion. Introduction of President-Elect Chas. O. Bond.

Thursday, 2:30 P. M.—Technical Session.

Thursday, 8:00 P. M.—Theater Party, Grand Opera House. Complimentary to visiting delegates and ladies.

A. E. R. A. CONVENTION

The annual convention of the American Electric Railway Association is to be held in Atlantic City, October 13-17. President Harries has issued a call urging executives, directors and heavy stockholders to attend the convention as well as those engaged in pure operating work, indicating that the parent association is considering many problems of vital interest to them and that detail matters have been delegated to the affiliated associations. The preliminary program indicates many subjects of great interest to railway men. Since 1911 some 15 000 sq. ft. of exhibit space have been added to the Pier layout so that the manufacturers' exhibit will undoubtedly be the largest in the history of the association.

ASSOCIATION ISLAND MEETING

The Association Island Corporation has invited the presidents of all the electrical associations, societies and leagues—national, state and city—to attend a meeting on Association Island. September 3-6. The following program has been announced:

"Government in Relation to Business," Mr. Wm. D. McHugh, Omaha, Nebraska; "Distribution of Electric Energy — Present and Future," Mr. Samuel Insull, president Commonwealth-Edison Company, Chicago, Ill.;

THE ELECTRIC JOURNAL

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General Railway Electrification

At any time during a period extending back at least ten years, it has been possible to provide technically satisfactory operation of heavy railways by electricity. During that period a few important installations have been made, and with results quite in accord with the calculations and predictions upon which they were undertaken. Compared with the total mileage of steam railways in operation in the world, the electrified mileage is extremely small, and especially so when we consider the extent of the application of electric power in practically every other industry. The query naturally arises—Why has the use of electricity in this field, wherein the electric motor seems especially fitted to serve, been of such slow growth? Why have not the oft-repeated and confident predictions of the past twenty years been more completely realized? Why are not thousands of miles of our steam railways operating by electricity instead of a few hundreds?

There is evidence of a growing interest on the part of railroads in the adoption of electric traction; and within the past year a number of important projects have arisen, one of which is described by Mr. F. F. Rohrer in this issue of the JOURNAL. There is, however, no evidence that the steam railroad managers of this country are intending, in the immediate future, to make a general substitution of electric for steam traction. Abroad there seems to be a more general movement in this direction than in the United States. In nearly every instance in the past, where electric traction has been installed by a steam railway, some special cause has led to its adoption. This is also the case with most of the projects now under consideration.

In the opinion of the writer, there are two principal causes that have retarded the development of the electric art as applied to steam railways, and the substitution of electric traction for steam.

In the first place, there has been a lack of agreement on the part of engineers as to the proper standards and systems to be employed, especially in the United States, which has naturally led the railroad managers to hesitate to substitute systems of traction concerning the sufficiency of which recognized authorities do not concur. The railroads today have, through a long period of coöperation, come to agree very largely on general standards to be employed, and one of the important factors in any general plan of steam railroad electrification is the necessity and desirability of agreement upon electrical standards which will permit, at least to a certain extent, of interchangeable operation.

In Europe, where the railroads are largely owned by governments, the future has been anticipated to the extent that these subjects have been considered by commissions appointed by the governments, and conclusions reached in many countries on fundametal electrical standards. No such agreements or conclusions have been reached in this country.

For a number of years, there has been carried on in the public press and elsewhere, a controversy which would lead a layman to believe that there was a much wider difference of opinion as to the efficiency of certain systems of electric traction than has actually been the case. As a matter of fact, competent authorities have all along been in substantial agreement and have recognized that most of the problems of steam railway electrification may be solved satisfactorily in more than one way, while at the same time recognizing that any system, which fulfills the requirements of successful operation, must of necessity embody certain fundamental characteristics which are well known and appreciated. It could scarcely be expected that railway managers would be unaffected by this controversy on the part of the misguided persons who have been fighting the imaginary "battle of the systems," and it would have been natural for them to draw improper conclusions as to the real attitude of those engineers and manufacturers who were and are actually creating and producing apparatus for such service.

The second, and after all the real impediment to the more general adoption of electrification by steam railways, has been the necessity for a definitive answer to the question, "Will it pay?" In other words, the subject is an economic one and involves the whole question of railway finance and economics, and it is obvious that no argument will appeal to a railway manager in this day of railroad regulation and difficult railway finance that does not spell definitely a saving in dollars. This saving may come from lower operating costs, by increased capacity, or by one of the hundred different ways which may suggest themselves as being incidental to electric operation.

It is a fact that it cannot now always be shown that electric operation will effect an attractive saving and, in many cases, it will not be possible to show this until conditions develop in the situation of individual roads which will alter their economic position. Not until that time comes in the history of various railroads will we see that general adoption of electric traction for which we all hope and which, while making railroad travel so much more agreeable, will mean at the same time a real economic gain.

L. A. Osborne

The Year's Progress in Railway Development

A year ago the writer outlined for the Journal the various important advances in electric railway work which had been made in the preceding year, and expressed the belief that the coming year would show even greater improvement. This prediction has been fully justified. The past year has shown a steady and healthy growth in all lines. The demand for light weight equipments and high efficiency in operation has continued. There is a real and logical reason underlying this demand—it is not simply a fad. This is the day of efficiency, or at least the demand for efficiency, and such a demand is bound to be satisfied. The only danger in it lies in carrying methods to an extreme. The tendency is to reduce weights to such an extent as to greatly increase the cost of maintenance, and thereby produce just the opposite result from that desired. Excess weights should, by all means, be removed from all parts of the equipment, but beware of cutting into the weights of useful material.

The means for securing the minimum consumption of energy with railway equipments are fairly well known, but need continual repetition. Rapid acceleration and braking, long coasting periods, reduction of resistance loss by use of field control and proper gear ratios, and lastly, the reduction of dead weight and friction, will give the smallest power consumption. Not all roads are in a position to procure at once light weight equipments with field control, but practically all can secure the economies resulting from rapid acceleration and braking, and elimination of unnecessary stops.

The continued efforts of designers toward the improvement of railway motors will, doubtless, result in the ultimate production of a motor which will correspond to the Deacon's "Wonderful One Hoss Shay," every part of which was as strong as any other part, so that the "Shay" ran for many years until finally the entire carriage collapsed. If the motors do not eventually reach this state of perfection, we know, at least, that each year will see the introduction of new features which will increase the reliability and efficiency and decrease the cost of maintenance.

Inspection of the new motors on exhibition at the Atlantic City Convention of the American Electric Railway Association will show of what this year's improvements consist. No radical changes have been made; one tendency appears to be towards the use of pressed steel shapes for gear cases, motor covers, dust guards, etc. It will be found that the use of dust guards surrounding the axle, especially for interurban motors, will effect a great saving in the cost of maintenance. Axle bearings have a fashion of collecting enormous amounts of dust and sand, in some localities, which grind out the bearings, reduce the size of journals and increase the end play of the motor so fast as to require very frequent overhauling. The new dust guards will prevent this to a very large degree. The new axle bearing built without separate key or dowel should also be studied.

The use of multiple-unit control for city cars will, undoubtedly, be greatly increased by the advent of the pneumatically-operated type of drum control, which is now in use on the new stepless cars of the New York Railways. As this control is fully described in the article by Messrs. Hall and Riley in this issue, it is not necessary to more than mention it here, but it is certain that the ability to secure multiple-unit operation by simply adding the pneumatic operating head to any standard "K" controller will greatly increase its popularity. The control wiring is of the very simplest form, and automatic acceleration, which prevents the abuse of the equipment, can be secured easier than with any other known form of multiple-unit control. With this control all the many advantages of multiple-unit service for city cars can be secured.

The past few months have witnessed the inauguration of one of the most important steam railway electrifications that has yet been projected. This is the electrification by the Norfolk & Western Railway of its Elkhorn Grade-Bluefield division, between Bluefield and Vivian, W. Va., including thirty miles of main line. It is very significant that this line is to be equipped for operation with single-phase, alternating current, at 11 000 volts. The locomotives are of a type especially adapted for heavy freight service on mountain grades. The use of the polyphase induction motors for driving the locomotive, while still maintaining single phase on the trolley, gives the locomotive the advantage of all the rugged constructional features of the induction motor, and also the ability to hold a train on down grade by regeneration. This is the first example of really heavy freight haulage over such distances by electric locomotives, and the results, on account of the size of the electrification and the unique features in the locomotive, will be watched with the greatest interest by railway men generally.

Steam railways are appreciating, more and more, the advantages to be secured by electrification, and the next year or two will doubtless witness the development of a considerable number of projects equal to, or greater than, that of the Norfolk & Western.

N. W. Storer

Heavy Electric Traction

The substitution of electricity for steam in the operation of trunk line railways, like its substitution in any other industry, is a means toward the accomplishment of some desirable purpose and not an end in itself. As a rule the change is an expensive one. Frequently, it involves not only the motive power and rolling stock, but also the signal system, terminal arrangements and other items.

It is unreasonable to expect that the operating cost of doing anything by one or the other of two alternative modern methods should differ so greatly as to warrant a change from one to the other on the basis of cost alone. Buildings already piped for gas are wired for electricity, not to reduce the lighting bills, but to obtain greater convenience and better illumination. Likewise, factories using steam engines install electric motors, not so much to reduce the power cost as to obtain better speed control, greater output and more healthful working conditions.

In the same way electric locomotives or motor cars are adopted in the place of steam locomotives in order to eliminate smoke and gas from tunnels, to obtain more flexible operation for suburban service or to secure higher speed and consequently greater track capacity on mountain grades. In other words, steam railroads, like factories, are electrifying to improve the quality or increase the quantity of the service which constitutes their output. Two very instructive articles in the present issue of the JOURNAL, one by Mr. W. S. Murray and the other by Mr. W. R. Stinemetz on this subject, go to show that steam engineers have not been idle and have so perfected the steam locomotive that there are today numerous operating conditions in which it continues to show considerable superiority over the electric locomotive. On the other hand, there are other conditions, such as tunnels, terminals and grades, where the electric locomotives have a very considerable advantage over steam locomotives. For these reasons it is apparent that for some time to come steam road electrifications will be confined to such problems as, on engineering analysis, show such promise that both the electrical engineer and the experienced railroad man will join hands and agree on the best course of procedure.

Even under these conditions it is not difficult to foresee as large an amount of new electrification work as the manufacturers of electric locomotives can reasonably take care of for years to come. The rate of heavy railroad electrification at the present time is not such as to give the manufacturer as steady a load on his plant as is to be desired. At the same time, the number of conjested points, terminals and severe grades throughout the country is such that their electrification alone means that a large amount of electric locomotives, generating apparatus, etc., will be required. Meanwhile, the development of the problem of heavy railroad electrification will doubtless be continued to a point where electric locomotives will be even better fitted to supersede steam motive power than at present.

C. S. COOK

What the Single-Phase System Really Is

In the minds of some engineers, the single-phase railway system appears to be confused with the single-phase commutator type railway motor. They overlook the fact that this motor represents merely one method of utilizing the single-phase system. The fallacy is the same as if one confused the polyphase induction motor with the polyphase alternating-current system.

The possible advantages of a single-phase alternating-current railway system were realized long before any good methods of utilizing such a system were developed practically. The use of motor-generators on locomotives, the motors of which would receive alternating current from the trolley line, while the generators would supply current to electric motors driving the axles, was suggested long ago. Also, over eleven years ago, Mr. B. J. Arnold worked out a single-phase railway system, in which a single-phase induction motor operated an air compressor, the car axles being driven by compressed air motors. This was a true single-phase railway system, although no commutator type single-phase motor was used.

It is obvious, therefore, that such a railway system is something other than the driving mechanism on the car or locomotive. Therefore, a broad definition of the single-phase railway system is not out of place. It may be defined briefly as *the application of single-phase power to a trolley system for car propulsion.* Any particular method of transforming the alternating-current power to axle-turning effort is a secondary matter, as far as the system is concerned, although it may be of primary importance where any special torque characteristics are desired.

The essential features of the single-phase system lie (1) in the use of a single current or circuit, thus requiring but a single trolley conductor, and (2) in high voltage on the trolley system, with corresponding reduction in current, thus increasing the facility for transmission and collection of such current, and (3) in the facility of voltage transformation of the alternating system which allows the use of one voltage on the trolley system and a separate and lower voltage on the car equipment, and (4) economical speed control by means of voltage control in those types of equipment where the two are inter-related.

With the above defined general system, various types of equipment be used, depending upon the kind of service, etc. In this direction, many possibilities are presented. For example, equipments using single-phase commutator motors, such as on the New Haven Railroad, the St. Clair Tunnel, the Hoosac Tunnel, the Spokane & Inland Railway, etc., may be used. For mountain grade work, in particular, and many other services, in general, the so-called split-phase or induction motor type of equipment may be used, such as the Norfolk & Western Railroad has contracted for recently. Again, among the very promising possibilities is the vapor rectifier type of equipment, in which a rectifier is installed between the step-down transformer and the motors which drive the axle, these latter being of the usual direct-current type. Such an equipment would utilize the ideal features of the single-phase system and of direct-current equipment. A fourth possibility lies in rotating commutating apparatus for supplying suitable current to the axle motors. Additional possibilities lie in the use of frequency converters, motor-generators, or other devices, which can receive single-phase alternating current of a given frequency, and transform to any other desired form suitable for operating the axle driving motors.

Any of the above types of equipment could operate over the same single-phase system, provided they are built for the same frequency and voltage. One railroad, for instance, might have one type of equipment, while another might have an entirly different type, and yet either equipment would operate over the other company's lines, if the voltage and frequency were the same for both. Or, one railroad might have different equipments on different parts of its system, depending upon service conditions. Or, two or more types could work over the same line. For instance, on a grade, it might be advantageous to use freight locommotives of the split phase type, while passenger locomotives requiring a much wider range in speed might be of the commutating motor type, or of the rectifier type, assuming the latter to be a future possibility. For terminal operation, yard work, etc., where frequent acceleration is required, one type of equipment could be used, while a radically different type could be used for the main line service, if desirable. Furthermore, equipments used on light branch or feeder circuits, could run on the main line with equal facility.

It would appear therefore that the single-phase system, taken in its broad sense, presents possibilities not found with any other general system yet proposed. At present the system allows the use of two radically different types of equipment, namely, the straight single-phase and the split-phase, while certain other types present very great possibilities. Thus the system appears to be broadening out in its application, instead of narrowing, which is a most promising feature. With this one general system, terminal and yard work, main line service, tunnel operation, mountain grade work, branch lines and feeders, etc., can all be handled. B. G. LAMME

Multiple-Unit Operation of City Cars

The inadequate character of the rush hour service in nearly every large city and the necessity for some practical method of improving it, give especial interest to the article by Mr. F. M. Loud, of the Public Service Railway Company of Newark, N. J., on "Train Operation in City Service." In describing the results obtained by his company in a comprehensive series of tests made to determine the desirability of two-car train operation, Mr. Loud calls attention to a number of features which will probably be found true in many other places, as well as in Newark. One of the most important items brought out is the fact that a two-car train can clear a crossing in eighty percent of the time required by two single cars. This means that instead of 520 cars which now pass the corner of Broad and Market streets during the evening rush hour. the number could be increased to 650 cars if all were operated in two-car trains.

It is ordinarily supposed that, on account of the larger number of people carried by a two-car train, many more stops must be made than with a single car, and the schedule speed thus reduced The tests show, however, that the increase is not nearly as great as might be expected. After a certain total number of passengers is reached, any further increase seems merely to result in more persons getting on or off at each of the various stops, rather than in any great increase in the number of stops. As a result of this it was found that the multiple-unit trains, even when handicapped as they were by the unfamiliarity of their crews and the public with them, made practically as good time over the entire route as single cars, while in the congested districts they were able to make even better time.

In comparing multiple-unit train operation with the use of motor cars and trailers, it was naturally found that, on account of the slower acceleration and reduced running speed, the trailer combination lost time badly on most of the test runs, thus showing that the use of trailers for rush hour service reduces the schedule at the very time when it is most desirable to maintain it. Entirely aside from the speed question, Mr. Loud points out a number of other disadvantages of trailers for city service, which entirely disappear when all cars are equipped with motors and multiple-unit control. It was found also that in snow or sleet storms, and at other times when the rails are in bad condition, the use of multiple-unit trains had a decided advantage over the use of single cars, since the first car removed the snow or sleet and left a good rail for the second car.

In general, the article shows very clearly that train operation offers a number of desirable features, even for congested city service, and that these can be secured much more readily by means of multiple-unit trains than by the use of trailers. Thanks are due to the Public Service Railway Company for the broad-minded way in which they have given out so freely the results of their investigation on this subject.

C. Renshaw

The Low Floor Cars

A year ago the Journal gave considerable space to the low-floor car and its equipment, as developed by Mr. P. N. Jones, general manager of the Pittsburgh Railways Company, who deserves much credit for having the courage of his convictions in resorting to extremely radical designs to meet modern requirements. The success of the initial equipments has resulted in the ordering of fifty additional motor cars and several double deck cars.

The article in this issue by Mr. E. L. Stephens, master mechanic of the Los Angeles Railway Company, is a concrete example of the real progress that has been made in reducing weights and increasing passenger capacity of cars and, at the same time, introducing the center-entrance and pay-as-you-enter features which have apparently proven successful. In this instance, the seating capacity has been increased from 44 to 54 persons, and the total weight of the car has been reduced 500 pounds.

The writer, while visiting the Pacific coast, about a year ago, was deeply impressed with the characteristic progressiveness of the electric railway properties at Los Angeles. On account of the great distance from the source of large Eastern manufacturing and supply houses, it might be expected to find the general development to be somewhat behind Eastern standards, but the reverse was found to be true. It was interesting to observe the up-to-date methods of maintenance and inspection, the general appearance of the entire rolling stock and car shops, and, above all, the careful study that had been given to the great economy that is secured through adherence to fixed standards; and the fact that the standards had been brought up-to-date from time to time. The idea of adherence to obsolete standards, with its resultant high maintenance cost, was nowhere to be found. It will be noted, in the article by Mr. Stephens, that this same creditable policy has been continued, and while they have increased the capacity of the cars, adopted center entrance, etc., adherence to standard equipment and general detail structures has been economically worked out.

Another notable instance of progress in the low-floor type of car is the one-man prepayment low-floor car of the Illinois Traction System, which was worked out by Mr. J. M. Bosenbury, superintendent of equipment, who directed the construction not only of the car bodies, but also of the control equipment, which is of the single-end, light weight unit-switch type, and the "baby" type of motors developed for Mr. P. N. Jones. This car weighs, completely equipped, twenty-three thousand pounds. It is reported that during the rush hours ninety passengers were carried comfortably in one of these cars.

The stepless cars for the New York Railways Company are exceptionally noteworthy in that the transportation problem to be solved was more difficult than that which obtains in any other city in the United States, on account of the congested conditions on the main thoroughfare—Broadway. Messrs. Hedley and Doyle, of the Interborough Rapid Transit Company, worked out this intricate problem and specified certain ideal requirements for the control of the motors, door mechanism, signals and couplings and coöperated with the manufacturer in working them out. The type of control finally developed is described by Messrs. Hall and Riley in this issue. The first equipment, which has been in service about a year, has proven conclusively that, with American ingenuity behind it and with the railway operating men coöperating with the manufacturer, nothing seems impossible of accomplishment.

Mr. Terrence Scullin, master mechanic of the Cleveland Railways Company, has worked out a very ingenious arrangement for the new low floor, side entrance cars which have been adopted in Cleveland. Each of these cars is to be equipped with four 40 horsepower motors, designed to give standard clearances under a minimum wheel of 26 inches.

The new center entrance cars, which have been placed in service by the Brooklyn Rapid Transit Company, have received very favorable comment from everyone who has had the good fortune to see them in service. The detail designs and structure of these cars are very original and were the result of a very careful analysis of traffic requirements in Brooklyn and elsewhere.

The low-floor, center-entrance cars of the Washington Railways Company have also worked out very satisfactorily in that city.

M. B. Lambert

OAKLAND, ANTIOCH & EASTERN RAILWAY

C. E. HEISE and G. B. KIRKER

THERE has now been completed a high class interurban electric railway system intended to afford the shortest possible route combined with fast transportation facilities between San Francisco, the principal city and seaport of the Pacific Coast, and Sacramento, the capitol of the State of California and center of a vast interior agricultural territory. The Oakland, Antioch & Eastern Railway, like all railroads excepting those entering San Francisco from the South, has its western terminus on the eastern shore of San Francisco Bay, the shops, car barns, yards and depot, being located at 40th Street and Shafter Avenue, Oakland.

A traffic agreement existing with the San Francisco-Oakland Terminal Railways, permits the Oakland, Antioch & Eastern Railway to operate its cars over the "Key Route" tracks from 40th Street to Shafter Avenue, to the Key Route Pier, from which point passengers are transferred to San Francisco on the high-class ferry steamers of the Key Route System. Through this traffic agreement, the Oakland, Antioch & Eastern Railway are enabled to take passengers from San Francisco through to Sacramento and intermediate points without any change of cars after the passengers have once transferred from the ferry boat to the waiting electric trains at the Key Route Pier.

The cities on the eastern shore of San Francisco Bay are separated from the interior sections by a range known as the Contra Costa Hills, part of the Coast Range Mountain system, which offered such engineering obstacles to the construction of a railroad, that heretofore no company has attempted to build through them, although it was realized that a satisfactory route through these hills would materially shorten the distance to interior points and also open up a virgin territory. The territory between the eastern slope of these Contra Costa hills and Sacramento, is practically level, but offered construction difficulties because of the necessity of crossing several sloughs and marsh land, also a narrow arm of San Francisco Bay and the Sacramento River.

Starting from the "Key Route" pier, the electric trains of the Oakland, Antioch & Eastern Railway run over the 600 volt system of the "Key Route", a distance of approximately five miles to the western terminus and depot of the Oakland, Antioch & Eastern Railway, where a stop is made to pick up passengers. Leaving the Oakland terminal, the track extends out Shafter Avenue, in a northerly direction for about 1¼ miles through a good residential district and continues for some additional distance through one of the best new suburban residential districts of the East Bay section.

Very shortly the climb commences up the grade to the tunnel which pierces the Contra Costa hills. Leaving Oakland, the grade is 1.5 percent for some distance, increasing to 4.1 percent for about 4 000 feet, then there is a level tangent about 300 feet long and the up grade for the balance of the distance to the western portal of Shepard Canyon tunnel is 2.4 percent. This tunnel is the only one on the system and has a length of approximately 3 700 feet, and slopes to the East on a uniform grade of 1.9 percent. The driving of this tunnel presented some very interesting engineering problems because of the character of the ground encountered. The Eastern half of the tunnel is driven through rock, which presented no particular difficulties, a heavy timbering of standard construction being sufficient to properly hold the ground. However, in the western end of the tunnel and the approach, considerable difficulty was encountered due to swelling of the ground after the approach had been opened and a considerable portion of the tunnel driven. It finally became necessary to place a concrete lining in the western end of the tunnel and heavy reinforced concrete retaining walls were constructed at the western portal together with reinforced concrete floorings in the shape of an inverted arch. · This construction has proven singularly effective and absolutely no trouble has been experienced since the completion of the tunnel.

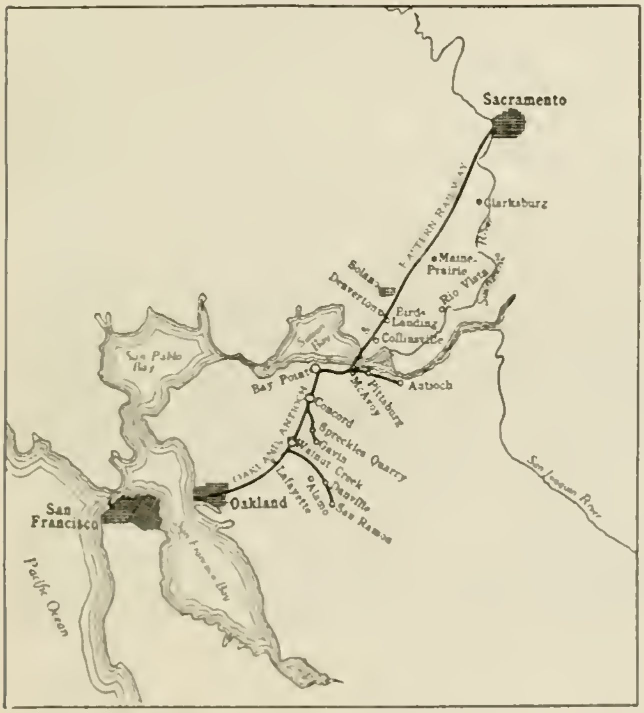

FIG. I—OUTLINE MAP SHOWING LOCATION OF OAKLAND, ANTIOCH AND EASTERN RAILWAY

Leaving the tunnel, the road extends through Redwood Canyon, one of the most picturesque spots in the State, the grade continuing to descend in a generally eastern direction and varying from 1.9 percent to practically level track, until the village of Lafayette is reached, 16 miles from the Oakland terminus. From this point, the road traverses a rolling country through the towns of Walnut Creek and Concord. This section, while really not far distant from San Francisco in an air line, has had its development held back because of lack of transportation facilities. From Concord, the road extends to Bay Point, a rapidly growing manufacturing center, where there is a junction with the trans-continental Southern Pacific and Atchison, Topeka & Santa Fe Railways.

Leaving Bay Point, the tracks parallel the transcontinental railroad systems for some distance and then cross beneath them, thus eliminating the danger of a grade crossing at this point. The construction of this under-pass was no small problem, as the cut is approximately 1 600 feet in length, is built on a six degree compensated curve, the amount of material excavated was approximately 100 000 cubic yards, and the entire bottom and side walls of the cut are of reinforced concrete. The tracks of the two steam railroads are carried on steel deck trestles supported by concrete columns. From this under-pass, the tracks extend to the South Ferry slip, where the electric trains are run onto the car ferry boat "Bridgit" and transferred across an arm of San Francisco Bay to the North Ferry slip on Chipp's Island.

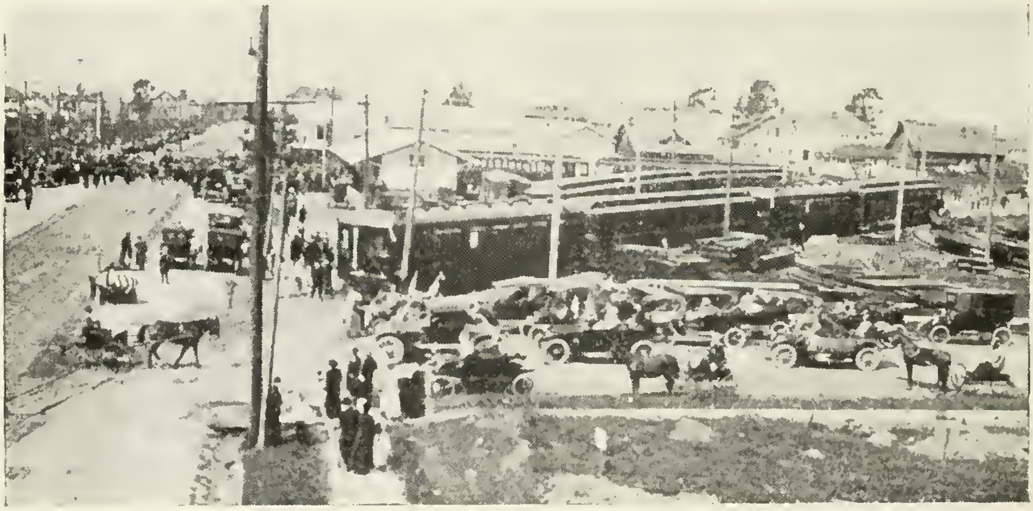

FIG. 2—VIEW AT OAKLAND TERMINAL WHERE CONNECTION IS MADE WITH "KEY ROUTE" TRACKS

The United States Government has given the company permission to erect a bridge across this channel, but several years will be required to construct it and the car ferry boat will serve until the bridge has been completed.

From the North Ferry slip, across Chipp's Island and Van Sickle Island, the road extends over marsh lands and sloughs. A fill has been made across the greater distance through these marsh lands, although some trestles have been constructed, and Montezuma slough is crossed by a center pier revolving draw-bridge about 250 feet in length. The line then reaches the main land, passing through the Montezuma hills and continuing through practically level country, where there is a stretch of 23 miles of tangent track, until the Yolo Basin is reached, from which point a trestle, approximately 14 000 feet long, carries the track up to a point near Glide Landing on the Sacramento River, from where the road continues on the river levee for about one mile and then continues along a tangent fill for about six miles, entering the city of Sacramento over a steel bridge crossing the Sacramento River at M Street.

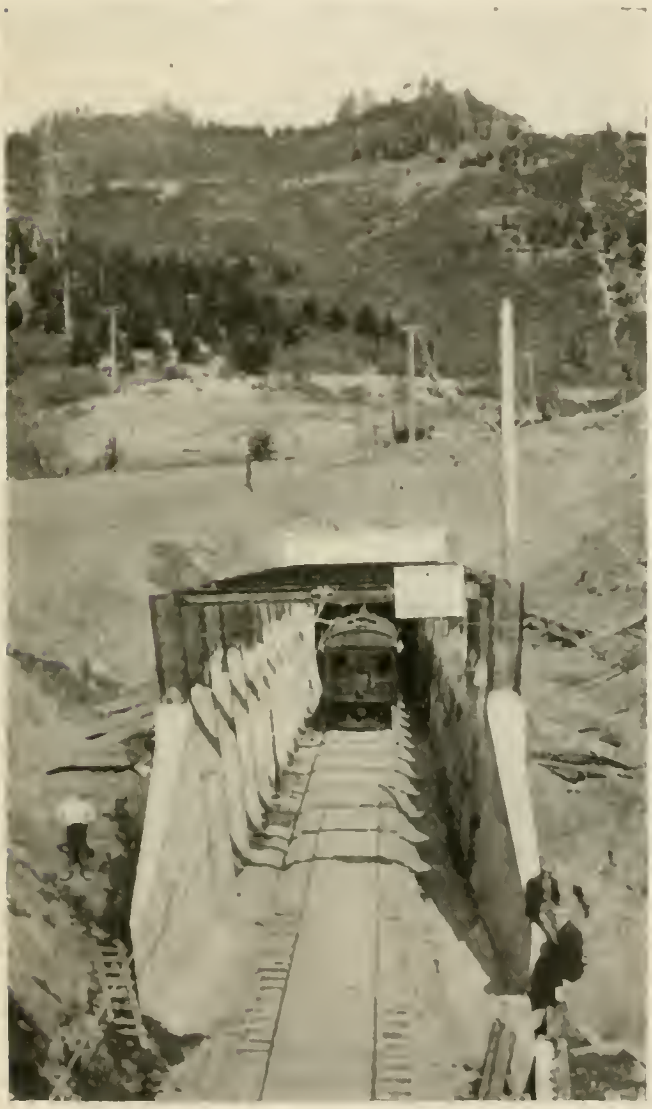

FIG. 3—WEST PORTAL OF SHEPARD'S CANYON TUNNEL THROUGH CONTRA COSTA HILLS
Showing unusual retaining wall.

After leaving Oakland the road is built on the company's private right of way the entire distance through to Sacramento, and in Sacramento the company has its own franchises and terminal sites, which are most favorably located.

The line throughout is standard gauge, single track, with a total of about 30 sidings, each of ample length. Standard 70-pound rails with electrically welded bonds are used. The entire length of line is very efficiently protected with electric block signals.

OVERHEAD CONSTRUCTION

Flexible single catenary overhead construction has been adopted as standard. The trolley is 4/0 grooved, hard drawn copper. Mounted on the poles above the bracket arms, are cross-arms, carrying the 1 200 volt direct-current aluminum feeders, the telephone wires and the block signal wires. Submarine cables cross Suisun Bay and Montezuma Slough, carrying the feeders, the telephone and the block signal circuits.

SUB-STATIONS

Upon leaving the Oakland depot and continuing over the entire length of road up to the M Street drawbridge, at Sacramento, the trolley voltage is 1 200 volts direct current.

Five sub-stations have been constructed. The one at Concord is of reinforced concrete, but the standard type of construction adopted for the remaining sub-stations, consists of a structural steel framework covered with galvanized corrugated iron.

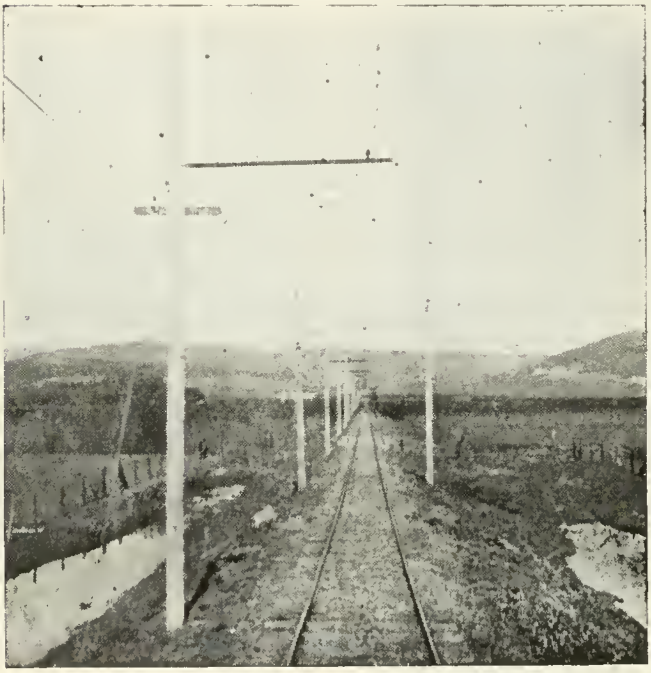

FIG. 4—VIEW ON A TANGENT.
Showing line construction.

The five sub-stations are located approximately as follows:—

Substation No. 1 is located at the eastern portal of Shepard Canyon Tunnel, approximately 6.4 miles from Oakland and is to contain three 750 kw motor-generator sets with switchboard equipment.

Substation No. 2, at Concord, 25.7 miles from Oakland, is to contain two 750 kw motor-generator sets, with switchboard equipment.

Substation No. 3, at Montezuma draw bridge, 44 miles from Oakland is similar to No. 2.

Substation No. 4, at Maine Prairie, 57 miles from Oakland, is similar to No. 2.

Substation No. 5, near Glide's Landing, 78 miles from Oakland, is similar to No. 2.

The standard unit adopted for these sub-stations is covered by the following description:—

A 750 kw. two-bearing, synchronous motor-generator set consisting of—one 750 kw compound-wound, 1 300 volt direct-current commutating pole generator, speed 514 r.p.m., is mounted on common shaft and bedplate with one 1 080 hp self-starting synchronous motor, wound for 11 000 volts, three-phase, 60 cycles; and one 19 kw, direct-current, 125 volts, direct-connected exciter, complete with necessary field rheostats and apparatus for starting set from the alternating current side.

The switchboard equipment for each motor-generator consists of—

1—Synchronous motor panel;

1—Direct-current generator panel, and

1—Negative circuit breaker panel.

Also in each sub-station there are three direct-current feeder panels.

ROLLING STOCK

The standard passenger car was adopted after careful consideration and consists of a combination car containing passenger, smoking and baggage compartments. It has an over-all length of ap-

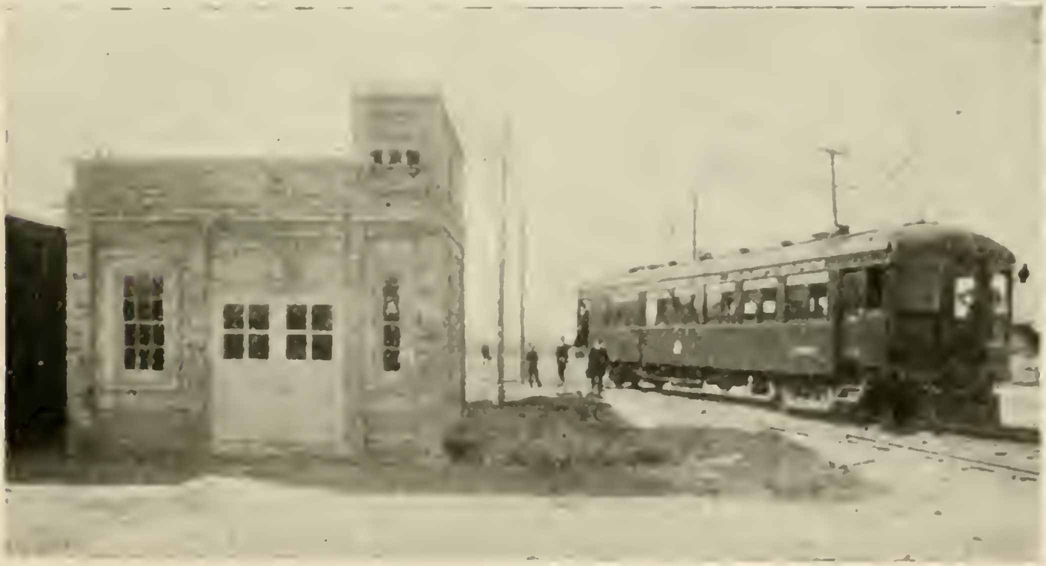

FIG. 5—SUBSTATION AT CONCORD AND STANDARD CAR

TABLE OF DISTANCES.

San Francisco to 40th street and Shafter avenue, Oakland......		7.9 miles
Oakland to East Portal of Tunnel....................	6.4 miles	
Oakland to Lafayette	16.0 miles	
Oakland to Walnut Creek	19.4 miles	
Oakland to Concord	25.7 miles	
Oakland to Bay Point	31.4 miles	
Oakland to West Pittsburg	37.0 miles	
Oakland to Montezuma	44.4 miles	
Oakland to Maine Prairie	50.6 miles	
Oakland to Glide Landing	78.2 miles	
Oakland to Sacramento Depot	85.1 miles	85.1 miles
San Francisco Ferry Depot to Sacramento Depot...............		93.0 miles

proximately 56 feet and seats 50 passengers. Each of the 14 interurban passenger cars of this type is equipped with four 600-1 200 volt commutating-pole railway motors and hand operated multiple-unit control. The control is designed for full speed operation on either 600 or 1 200 volts, a change-over switch making the necessary change in motor and grid resistance connections.

The total weight of the car, including air brake equipment, but without live load, is 87 300 pounds. The balancing speed of this equipment on level tangent track, with an average voltage of 1 200 volts, is about 50 miles per hour. With an average voltage of 1 100 volts, the balancing speed on level tangent track is approximately 48 miles per hour. The gear ratio is 22:55. Each of the motor cars is intended to be capable of hauling a 25-ton trailer car. There are 14 trailer cars at present and each is equipped with master controllers so that a combination train may be operated from any car.

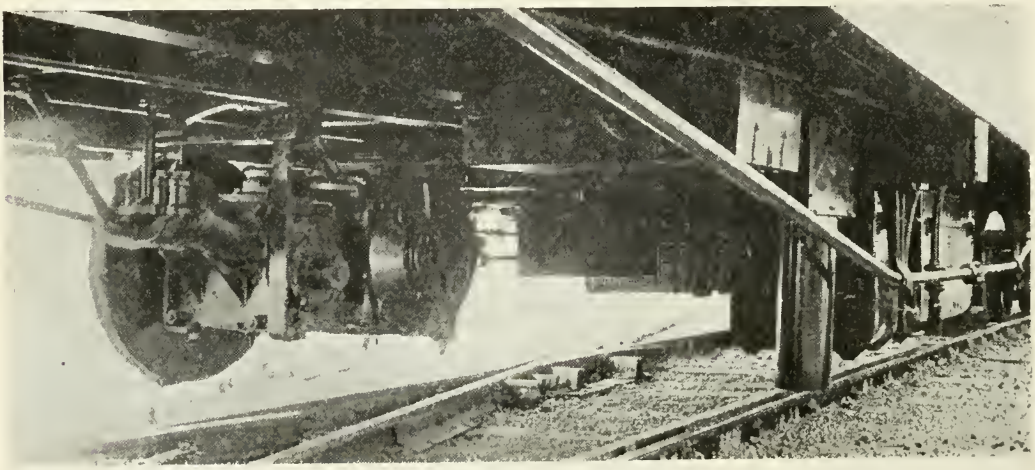

FIG. 6—STANDARD EQUIPMENT UNDER MOTOR CAR BODY

There are also two combination passenger and express cars of similar description. One car has a gear ratio of 18:59 and the other 16:61, so that these cars can be used for hauling a number of trailers or a freight car where necessary.

On account of the long and heavy grades, it was deemed necessary to insure a suitable supply of air available in any emergency, and for this reason two dynamotor-compressors were installed on each motor car, each compressor having a capacity of 25 cu. ft. of free air per minute.

To take care of the heavy through passenger business between San Francisco and Sacramento, two type 2-4-0, articulated truck, high speed electric locomotives are used, with four commutating pole, field control, 600-1 200 volt motors and unit switch control. Each locomotive is capable of hauling five steel passenger trailer cars, weighing 37.5 tons each, on level tangent track with 1 100 volts on the trolley, at a balancing speed of about 56 miles per hour. When hauling only three of these passenger cars, the balancing speed, under the same conditions, will be approximately 60 miles per hour. Each locomotive has a total weight of 62 tons, of which 43 tons is carried on the drivers and 19 tons carried on two radial pony trucks. The draw-bar pull is transmitted through the main truck side frames and each driving axle is equipped with an independent geared motor. The driving wheels are 42 inches in diameter and the gear ratio 26:47.

With forced ventilation the locomotive is capable of exerting continuously, a tractive effort of 4 400 pounds on normal field with an average of 500 volts, and 8 500 pounds for one hour on normal field at approximately 45 miles per hour with 1 200 volts, while with clean dry rails, the locomotive is capable of exerting momentarily a maximum tractive effort of 21 500 pounds. The motors have a nominal rating of 250 horse-power with forced ventilation.

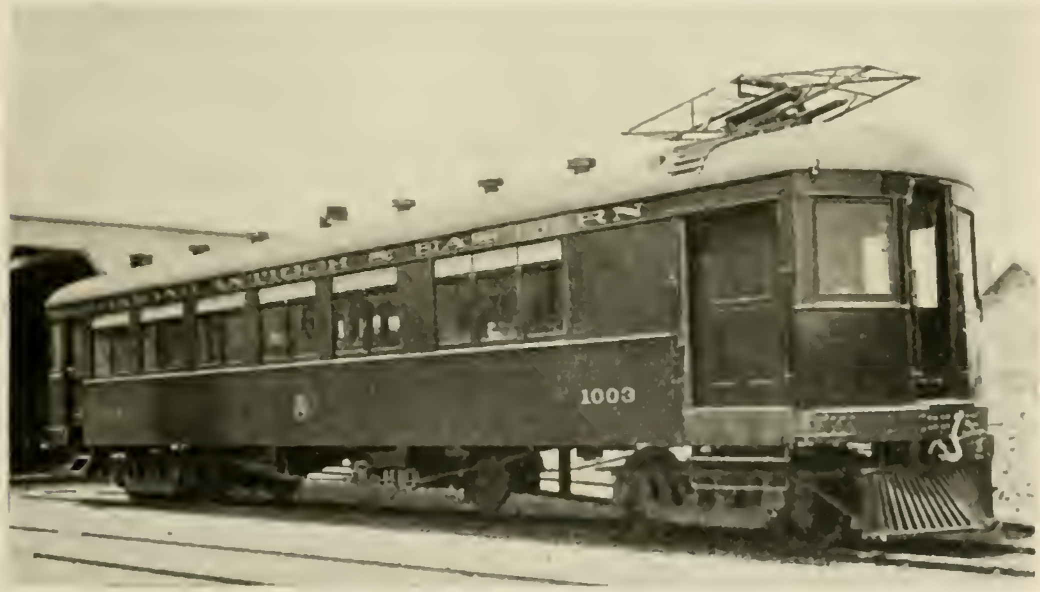

FIG. 7—HIGH-SPEED COMBINATION BAGGAGE, SMOKING AND PASSENGER MOTOR CAR

The motors and control equipment are designed for "field control," enabling the locomotives to exert relatively high tractive effort when the motors are operated on full field and securing maximum speed when the motors are operated on normal field. Each locomotive is equipped with two dynamotor-compressors, each compressor having a capacity of 35 cubic feet of free air per minute, and sufficient capacity to supply the required amount of

600 volt direct current for lighting the trailer cars, the locomotive headlight, and for operating the control. Mounted on the extended shaft of each dynamotor-compressor, is a blower which supplies the forced ventilation to the main locomotive motors.

For handling the freight business, there are two 47-ton freight locomotives, each equipped with four motors and hand operated unit-switch control, and using a gear ratio of 17:56 with 42-inch wheels. Each locomotive is capable of developing a full-load tractive effort of 16 600 pounds at a speed of 10.6 miles per hour with 600 volts, or a continuous tractive effort of 5 200 pounds with 600 volts, or a maximum tractive effort of 24 500 pounds.

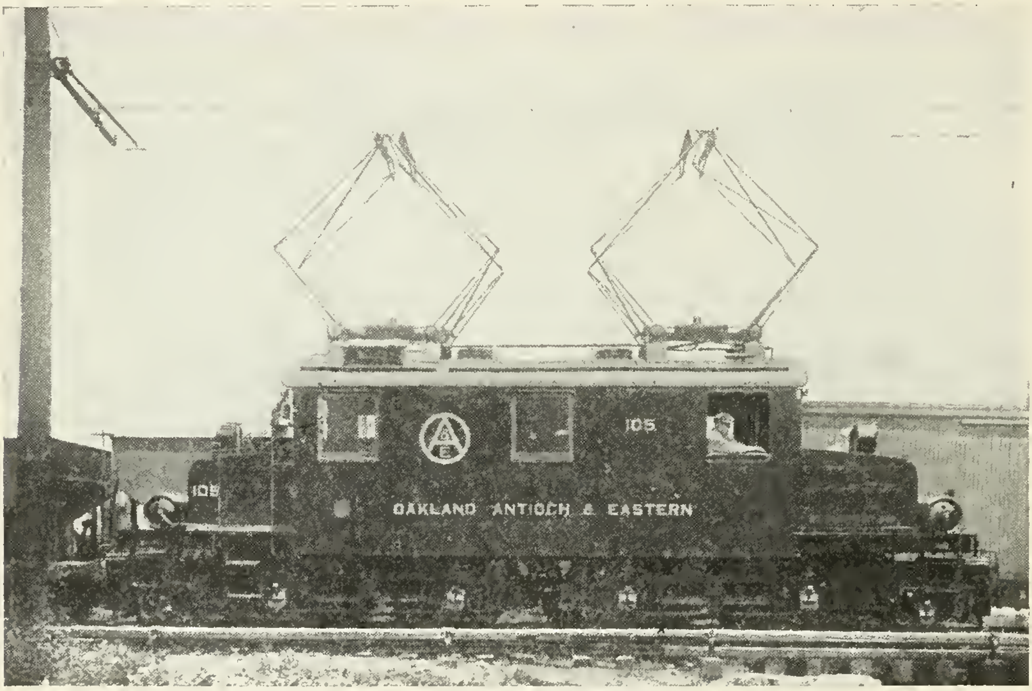

FIG. 8—OAKLAND, ANTIOCH & EASTERN LOCOMOTIVE

Each freight locomotive is provided with two independent dynamotor-compressors, each having a capacity of 25 cubic feet of free air per minute.

The passenger cars are equipped with roller pantagraph trolleys and the passenger locomotives with double shoe, sliding pantagraph trolleys.

The road was opened for service between Oakland and Bay Point in April, 1913, and through service between Oakland and Sacramento was inaugurated on September 3, 1913. Power is purchased from a long distance hydro-electric power transmission system at 11 000 volts, three-phase, 60-cycles, delivered to the various sub-stations.

HEAVY ELECTRIFICATION TENDENCIES

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TWO or three thousand years ago one of the old philosophers (Tacitus, I think it was) said, "There is nothing new under the sun." He was wrong. Electrification of railroads is new and is becoming "newer" every day. One of the newest things about it, and one of the most pleasant, is a change, a most significant change, in the general viewpoint of those engineers who are associated with electrification matters.

Gradually has come a clearer grasp of the fundamental principle that the problems inherent in the electrification of any important railroad are such as require not only a sound electrical knowledge and training but what is of even more importance, a fuller realization of the operating characteristics of the steam railroads it is proposed to electrify. Too often this point has been lost sight of, and electrification engineers cannot expect a patient hearing and a favorable attitude of mind from the operating officials of a steam railroad if, in the presentation of their case for electrification, they show a lack of appreciation of those vital and fundamental principles and practices that inhabit the thoughts of men in charge of the operation of such properties. Electrification engineers sometimes may be so thoroughly conscious of the many inherent advantages of what they have to offer that they forget to state, and in many cases fail to see, its limitations. The railroad man's just criticism of a proposition, some aspects of which are overstated, may be met with further overstatement. His natural objection to purchasing and wearing an ill fitting suit of clothes is met with assurances that the clothes really do fit him, but "that he doesn't know it."

Quite recently an important western road, whose traffic consists largely of heavy freight operating over stiff mountain grades, was under consideration for electrification, and the statement was made that, due to the inherent characteristics of the electric locomotive, it would be possible to approximately double the speed of freight trains over the electrified section. Evidence was given of the comparative tractive efforts and corresponding speeds of the steam locomotives in use and their electric rivals. The latter could easily maintain nearly double speeds at greater tractive efforts. There was no doubt about it, and it was inferred that the overall running time might be approximately halved with consequent reduction in operating charges and other expenses per mile. What was not regarded by the electrification engineer, and what was left for the railroad man to point out, was that the running time formed but a small percentage of the total time on the road—less than half in the case of the drag freights, of which the road's traffic was chiefly composed. Out of 100 minutes in actual service, 56 minutes were employed in loading up, waiting at yards and signals, attending to freight car brakes, etc. Only 44 minutes were usefully employed in running, so that the effect on speed of increased tractive effort could make its impression only upon 44 percent of the total time, representing an increase of 28 percent instead of the 100 percent which was confidently claimed. In the case of the way freights the percentage was less than this, and even with the fast freights, the running and waiting times of which were 67 and 33 percent, respectively, the increase was only 15 percent.

It is realized that increases in schedule of 28 and 15 percent are in themselves highly desirable and should prove attractive to any railroad man. The point is, however, not that the adoption of electricity cannot effect large and gratifying economies under certain conditions, but that greater care should be exercised in measuring them. This can properly be done only when the limitations and operating characteristics of the steam railroad and steam locomotives are clearly understood and appreciated, and with equal force when the limitations of the electric locomotive, together with its attendant power station, substations and contact wires are also realized and allowed for.

A point of superiority in the steam locomotive which has not heretofore been sufficiently acknowledged is its ability to cope with abnormal traffic conditions. It sounds like heresy to say that, in many respects, the electric system is less flexible than the steam system it proposes to replace. Yet that this is true an illustration or two will make clear.

Every one who has had much to do with the design of electric locomotives realizes how closely they have to be shaped to fit the confronting conditions of speed variation, grades, tractive effort, correct gear ratios and wheel diameters, and that when designed for one set of conditions or speeds, voltage, etc., they run but inefficiently when called upon to work for a time under different conditions. They must be operated closely to the conditions for which they are designed and it is matter for surprise to realize how narrow are these limits in many cases. There is a considerable difference in the flexibility of different kinds of electric locomotives themselves. The flatter speed curve of the direct-current railway motor, when compared with the speed curve of a single-phase series compensated motor, acts as a great handicap to the former as far as the speed flexibility of rolling stock is concerned; and, as is well known, both types differ again enormously in speed flexibility when compared with—say, locomotives fitted with two or three-phase induction motors. A steam locomotive has in many respects greater flexibility than any electric locomotive. This may be brought out in another way, by considering the behavior of both steam and electric locomotives under some abnormal traffic condition.

Suppose a bunching up of trains and tonnage to take place at some point on the system, due to a wreck, a broken wire, a short-circuit or trouble with signals. When conditions ahead have been adjusted and traffic may be resumed, the operating official in charge wishes to let his trains through, one behind the other, just as fast as his block sections will permit, and so make up time lost due to the breakdown. With a steam service there is nothing to prevent this. He can string his steam trains one behind the other just as close together as is consistent with safety, and so relieve the congestion. Each train is an independent unit, and may be so handled and regarded; not so, however, under electrification. Too many trains starting together impose undue peaks on the power house generators and, in the case of extended electrifications, with substations spaced at considerable distances apart, there are limiting conditions which enter in preventing the grouping of too many trains together between substations, either from lack of substation capacity to take care of the abnormal conditions or because of low speed due to low voltage conditions between substations. In other words, steam trains in emergencies may be despatched in fleets; electric trains *to the same extent* may not, and this condition, by taking away track capacity just at the time when the operating official most needs it, constitutes a weakness for the electrification proposition. To mitigate this there should be no skimping of either sub-stations or copper, and an electrification project which does not fully take into account and provide reasonably for these and other similar operating conditions cannot expect to be favorably regarded for the operation of the road.

The chief single reason withholding railroads from electrification today is the large capital investment required and the doubt in many cases of the ability under electrification to cover dividends on its investment. With this in mind, engineers who are presenting the claims of electrification should think twice before showing the smallest initial capital investment, and the largest return on this that they can; indeed it is to be feared that too often this feature tempts them to disregard the operating and engineering needs and present what is but an inadequate substitution. The writer is most optimistic of the present and future of electrification. Its field is wide. There are many railroad situations today which could be improved both as regards their operation and their economics by the carefully planned substitution of electricity for steam, but in making out a case for these we must not permit reliability to be sacrificed in the desire for cheapness. Reliability under difficult conditions is usually worth a high price, and this was never so true as in the case of the electrification of steam railroads.

Passing now from these more general aspects which need insistence, it may be well to review briefly the tendencies of the times as evidenced in developments in the various links of the electrification chain.

POWER HOUSES

Beginning with modern power houses, it is pleasing to note the great improvement which has taken place in the efficiency, not only in the main units in boiler house and engine room, but in the auxiliaries. Improved stoking and draft inlet arrangements, changes in details of boiler design; closer studies of heat transference and losses carried through from the fire boxes to the smoke stacks; closer watch of the CO_2 recorder, superheaters and other details; these taken together permit an output and a forcing of the boiler capacity that would have been incredible a few years ago. Similar changes and improvements have taken place in the engine room; and whereas overall thermal efficiencies of six and seven percent were and still are common in most stations, this figure has crept up yearly, until today overall efficiencies of twelve percent are being maintained in many instances, and there are one or two cases where even fifteen percent has been reached. This is fine progress.

TRANSMISSION AND CONVERSION

Electricity is the most efficient agent so far developed for transmitting large amounts of energy and collecting the same when and where wanted; but even so the losses in transmission are enormous. There are few large electrifications today wherein more than fifty percent of the energy generated at the power house appears usefully as work done on the drawbars of the trains. Somewhere in between, this fifty percent of the total energy is dissipated; some in the power house, a little in the primary transmission line, much in the substations, if these involve converting apparatus, and much in the secondary circuit unless the collecting voltage be high and the currents correspondingly low. There are losses, too, in the rolling stock, but these are comparatively small. Most of the losses occur either in the secondary circuit consisting of overhead trolley or third rail with track rail return or in the conversion of alternating to direct current in the substations. The lessons to be drawn from these are:—

1—That we must collect as small currents as are reasonably possible; this means high voltage on the contact wire.

2—We must wherever possible do away with the inefficient rotating apparatus required to convert energy from alternating to direct current, either motor-generators or rotary converters. There may be and doubtless are situations for which a voltage as low as 3 000 volts and a direct current may be the correct solution, but it is difficult to escape the conclusion that these adaptations will not be those which involve the transmission of large amounts of energy over an extended mileage of electrification. The tendency is for higher voltages on the contact wire and in several cases 15 000 volts has been successfully applied.

ROLLING STOCK

Continued progress is being made in the design of electric rolling stock. Manufacturers each year seem able to make a pound of metal possess a greater potentiality for work than previously. This arises from improvement in detail design. Control apparatus has been lightened and cheapened. A better arrangement of motors and other apparatus has resulted in lighter rolling stock and in a greater percentage of weight on the driving wheels. This progress seems likely to continue and the electric locomotive or multiple-unit car of today is a very highly developed piece of apparatus—simple, reliable and economical to operate.

The writer, however, would be loath to accept either of the two chief present types of locomotive motors (the standard series direct or alternating-current) as ultimately satisfactory solutions of the problem of electric propulsion of trains. It is believed that a more economical, reliable and cheaper piece of propulsion apparatus will yet be developed. Many interesting and significant experiments are being tried and in various parts of the world, embodying mercury arc rectifiers, split phase converters, motors having characteristics which are a compromise between the standard series and repulsion motors, and within this wealth of ideas and experimentation there will be developed the standard heavy traction units whose inherent designs will have application to the conditions they must satisfy.

Most significant of all, however, is the advance to accepted practical standardization of the overhead system of power supply and the disappearance of the consideration of the third rail in the field of heavy traction. There is but one reason for this. The overhead wire is the only type of construction that can deliver high voltage to the locomotive, and the complementary statement follows: that since no practical limitation on the manufacture of high potential alternating-current exists—while in the case of direct current a very positive limitation is to be reckoned with—the most natural combination has now arrived, viz: overhead, high potential, single-phase.

ELECTRIC RAILWAY PROPERTIES AND THE PUBLIC

CALVERT TOWNLEY

THE primary reason for building trolley lines is to transport people. Several secondary results follow, some of them always, others frequently. First the convenience of the communities served is greatly increased and their industrial activities stimulated; second, real estate values are enhanced and the communities taxable values thereby increased. These two results almost invariably follow trolley construction. If any one disbelieves this let him pick out the poorest trolley service coming under his notice and suggest that it be abandoned and the tracks taken up. Then note the opposition develop in the communities served. A third but not an inevitable result which follows building is a profit to the builders. Many other minor consequences also occur, but perhaps the above named primary reason and secondary results are all that need be here considered.

It is difficult to imagine any substantial community in this generation without trolley service. It may be doubted if any city can long hope or expect to progress without it, but must rather expect to fall hopelessly behind in its commercial competition with other places not so handicapped. The need of trolley transportation seems so obvious and its adequate supply in every community so important that even the brief recital of facts here sounds commonplace and unnecessary, yet search the columns of the press, the magazines, the minutes of our legislative bodies, federal, state and municipal, wherever trolley questions are debated, and do we find efforts put forth to get trolley service for communities now without it and to insure its suitable extension when once established? In the main, no. The primary subject for discussion, debate, ordinance or legislative enactment is to prevent the builders and operators of this almost invaluable utility from making too much money out of it. We have most completely put the cart before the horse and are devoting our energies unsparingly to the control of one of the three corollaries to the general proposition, and frequently without adequate consideration of the effect our actions are likely to have on the underlying primary object of securing transportation for the people. The present condition of affairs has come about quite naturally.

Trolley transportation has come to be an accepted necessary incident to the life of every community. We do not stop to rejoice in its possession any more than we do in that of having running water in our bath rooms. If any of us own property near a trolley line and its value increases our joy is tempered because our taxes are higher. Urban trolley service holds perhaps a more intimate relation to our private lives than does any other utility. Its cars are constantly before us. We must see and hear them even when we are not using them, and every time we use them we pay money, instead of only every month or quarter, as with other utilities. Delays and defects of service are self-advertised matters of public knowledge. We remember inconveniences or discourtesies from subordinate employees and, consciously or not, hold those at the top responsible. These facts and others have operated to create and foster antagonism against the utility companies themselves, which takes the natural shape of adding to their burdens and of restricting their earnings, usually with insufficient consideration for what should be the controlling factor, namely: Adequate present *and future* service to the people.

Humanity is selfish. We are apt to talk about our own troubles. Wherefore, when the trolley company, smarting under injustice perhaps, has sought relief it has tried to prove injustice by talking about its trouble and frequently meeting the response, "You have brought it on yourself by past sins." Now here we have the root of the trouble, too many people think the punishment of a utility company doesn't affect themselves, so "Why not soak them and get square?"

The object of this article is to emphasize this fallacy and try to make it clear that the public and not the company has to suffer. The futility of urging forgiveness, liberality or even fairness for *his* sake for someone who, up to now, has got the best of us is well known. But once we are convinced that such action will pay *us,* we are much more likely to be fair to him for our own sakes.

Now how does a community, not at present supplied, get trolley service, and how does a community that already has trolley service keep itself up to date? It seems needless to consider municipal ownership and operation because that method has not been adopted in this country and with us, consequently, is as yet an academic question. Therefore, trolley service must be provided by private capital. Every utility increases service as some function of the increase in population. Statistics of past growth in general support the statement that trolley gross earnings and therefore trolley service increases more rapidly than population; in large cities more nearly as the square of the increase in population. More service means more cars, larger power houses, bigger feeders, additional car barns and, as the community expands, additional tracks, all of which of course means additional capital. Authentic records show that over a term of years the amount of this additional capital put into a large number of properties has averaged between the limits of a minimum of $3, and maximum of $5.50 for every $1.00 of additional gross earnings received. Obviously additional capital from three to five and a half times its earning power cannot be taken out of earnings and therefore there must be some source from which a continuous supply of new money flows. Now where can this money come from? A popular conception is that it comes from a banker. Where does the banker get it? When he subscribes for stock does he expect to invest his own money? Certainly not. No banker's private fortune could long withstand such drains. Two of his most valuable assets are his public credit and his private clientele. By subscribing he keeps his credit back of the enterprise and enables it to be. He also secures for his clientele opportunities for investment not otherwise available. Both services are distinctly valuable and the banker is entitled to a profit for his performance. Without his reputation as a financier his subscription would have little value. Without a reputation for business sagacity his clientele could never have been acquired. But these facts mean that funds for trolley betterments must come from individuals—yourself and myself and any one else who has money to invest.

It has long been recognized that local sources cannot be relied upon to supply the continued capital demands for a community's utilities. Frequently the supply is insufficient and sometimes the stability of the enterprise or the responsibility of its managers is questioned. These facts and others brought about a syndicating movement which, during the last few years, has spread rapidly over the whole country, whereby a combining of the utilities of several communities into one corporation, backed by substantial people, has largely removed the limiting conditions named and capital for betterments now comes from sources outside the territory benefitted.

Now why should you or others invest your savings, say for example, in a trolley property in Montana or any other point remote from our respective homes where we have no interest in or responsibility for the welfare of the community served? Obviously because we anticipate bigger returns on our money there than elsewhere. Certainly, without such expectation, no one would put money into a Montana trolley. To be an attractive investment after paying all expenses of every nature there must still remain from each added dollar of gross earnings enough to yield a "satisfactory" profit on the from $3.00 to $5.50 of new invested capital required to produce it. Please note that it must be a "satisfactory" return. This means "satisfactory" to you and me and to the other investors, no matter what any Commission may rule to be a "fair" return, because investors only invest when and where they choose, let courts and commissions rule how they will. Trolley investments must compete with all others. They win or lose on their merits. Therefore, whenever in the investor's judgment trolley securities become less attractive than others, new capital will go elsewhere. Too much emphasis cannot be laid on this basic fact because it is the key to the whole situation and has been generally ignored in the unremitting and widespread strenuous effort to load trolley properties with new burdens. A common mistake is that of thinking of a trolley system as a completed affair, the money is not and cannot be got out, therefore, by suitable commission rulings or laws its earnings may easily be limited without the limiting power assuming the slightest responsibility for loss.

In the unrestricted past the experienced trolley builder could frame his own financial plan, dealing with municipalities for franchises and generally fix his own rate. Then the strong incentive for future profit justified the building of extensions through sparsely settled territory somewhat ahead of its transportation needs. The builder risked his money on his judgment, expecting that, although such territory might not immediately support a line, later it would build up and yield a profit both on the construction cost itself and also on certain additional securities as well, that is to say, on the much discussed and criticized watered stock. He used his credit and frequently his pocket-book, standing behind early deficits involving losses, hoping to recoupe himself later. There is no doubt that under these conditions many lines have been built much in advance of their commercial justification, thereby tremendously aiding rapid extension and development of the communities involved. The man of modest income could own his own home and raise a family of healthy children where land was cheap and sunshine and fresh air abundant and free. Without a fully developed trolley system this privilege rapidly shrinks. There is a long sad list of companies which have paid no dividends, many of them not all of their operating expenses and fixed charges. By no means all such lines as have just been described have been profitable, which is only another way of saying that trolley builders as well as others make mistakes in judgment.

In the last published report of the Public Service Commission of the Second District of New York, including all of the trolley properties of the state outside of Greater New York, the statistics of 71 operating companies show that, of these, seven paid dividends of 5½ or 6 percent during the year, four paid dividends of five percent, four of four percent and seven of lesser percentages varying from 1½ to 3 percent. The remaining 49 companies paid no dividends at all but the public received the benefits of the service just the same. Further, they will continue to receive benefits, because once built a trolley never stops operation, no matter who may make or may lose money. The incentive to build trolley roads has been one of the greatest factors in the growth of many of our thriving cities. Its removal will certainly operate in the reverse direction. In the last analysis what part of gross earnings stays in the company's treasury after all expenses have been deducted and is applicable to dividends, depends, of course, on the density of traffic.. It costs almost as much to operate a trolley car without passengers as it does with a full load and obviously, therefore, if a given number of cents out of each dollar earned are needed to attract new capital, then as the cost of operation per car mile increases, the number of passengers per car mile must also increase, that is, the cars must be more crowded; fewer cars must be run through thinly populated districts until such districts build up. Extensions must be deferred until the traffic has caught up to and has passed the facilities. This is not a personal opinion but the application of a general economic law to a specific case. A reiteration of the statements that the railroads have been greedy in the past and are themselves responsible for present antagonism will not change this law. Primarily we are not concerned with placing the blame.

but we are very deeply concerned about the existing facts. The writer is making no plea for trolley companies as such, because most of us pay money to instead of getting it from them, and do not care particularly whether they run at a profit or a loss. However, it is important to us to recognize the inevitable result of an effort concentrated on keeping down trolley profits but which ignores the country's needs. Are we pointing out a ghost of a far distant future trouble or is it at hand?

Statistics record that in the five year period, 1902-1907, 12 154 miles of trolley lines were put into operation in the United States, in the succeeding five years, to 1912 inclusive, the figure is 5 295 miles, a decrease of 56.4 percent, but the number of people needing extensions increased at about a uniform rate through both periods. A public utility commissioner in an important eastern state, which has a "splendid" public utility law, lives in a town where the trolley system has fallen behind and badly needs rehabilitation. Local capital has not been forthcoming for that purpose. His appeal to well known trolley builders and operators elsewhere developed the fact that, although these people were willing and even anxious to take up the enterprise, the state laws had been drawn so carefully to "protect" the public that no way could be found to induce outside capital to assume the risks of loss without a corresponding opportunity for profit. This is one recent instance where the trolley development must wait and the community sag behind and suffer for an indefinite time.

To one who may still think this discussion academic, it is respectively suggested that a comparison be made of American trolley lines and of the British tramways, with respect to the population per mile of track and the car miles run per annum per inhabitant. In Great Britain the restrictions have been more severe than they are in this country and the burdens greater, with the consequent inevitable result that there the tramways have been built only in the more densely populated territories. Great Britain has already reached the goal towards which we are speeding. If that is what this country wants, no attention need be given to this discussion. Let us continue to add burdens and to limit earnings and we will certainly get it.

THE NORFOLK & WESTERN ELECTRIFICATION

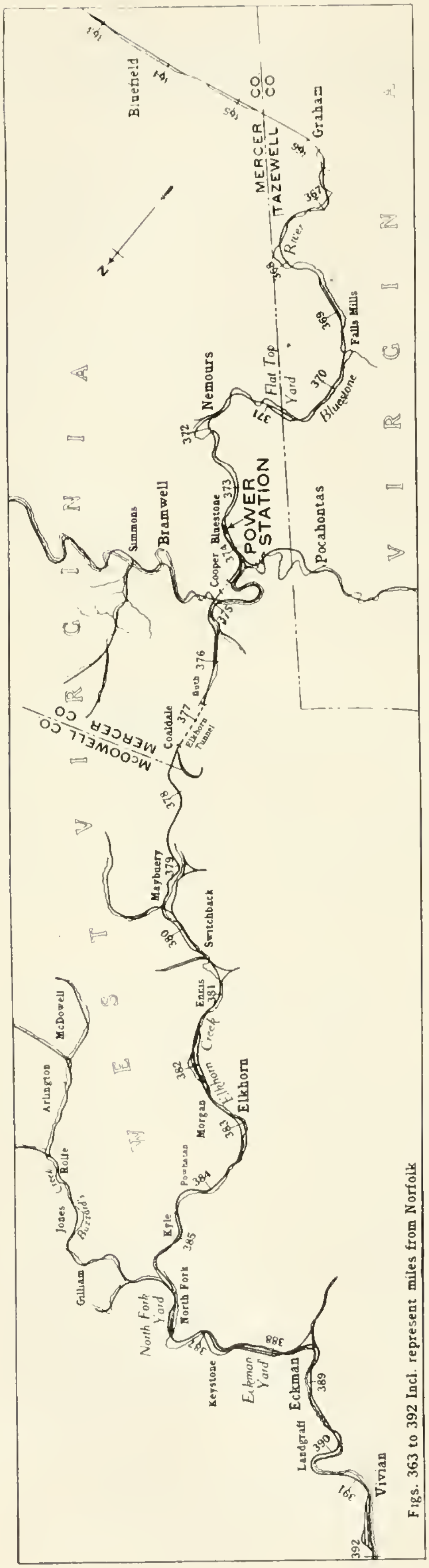
F. F. ROHRER

A MOST important development in the electrification of steam railroads is that recently announced for the Norfolk & Western Railway Company in the operation of their main line over the mountain grades betwen Vivian, W. Va., and Bluefield, W. Va., in the States of West Virginia and Virginia. Not only does this development mark an important step of progress in the use of electric energy as a motive power, but it forms another practical instance showing the advantages to be gained in heavy freight haulage by the use of electric locomotives. The traffic to be handled comprises the heavy coal train service originating chiefly at points along the Elkhorn Grade, the heaviest movement being upgrade. The reverse movement of empty trains and a certain amount of westbound coal is also to be handled electrically, or assisted upgrade by the electric locomotives.

The electrified section is about 30 miles long, extending from Vivian ,W. Va., to Bluefield, W. Va., as shown by the outline map, Fig. 1. The line is provided with numerous industrial sidings and passing tracks; also with storage and terminal yards and is double track throughout except at Elkhorn tunnel, which is single track. The grades range from a level track to a maximum of 2.5 percent against loaded trains, as shown by the profile, Fig. 2.

There are a number of tunnels in this section, all on tangent track with the exception of 850 feet of three degree curve at the east end of the Elkhorn tunnel. The tunnel near Cooper is about 700 feet long on tangent track and the Elkhorn tunnel about 3 100 feet in length. The height of the Elkhorn tunnel is 18 ft. 6 in. from the top of the rail to the crown of arch, and a maximum width of 14 ft. at a height of 10 ft. 6 in. above the rail.

Weight of Trains—East bound trains are to be made up either at Vivian, Eckman or North Fork, to a normal weight of 3 250 tons, and are run through to Flat Top or Bluefield; at Flat Top they may be filled out to 3 500 tons for movement to Bluefield. Trains of 3 250 tons may be operated through to Bluefield without filling out at Flat Top, and in that event the locomotives are to be capable of operating at approximately 28 miles per hour from Cooper to Graham. West bound trains are in general made up of empties as required, and run from Bluefield to points of distribution at the



Figs. 363 to 392 Incl. represent miles from Norfolk

FIG. 1—OUTLINE MAP SHOWING LOCATION OF ELECTRIFIED SECTION OF NORFOLK AND WESTERN RAILWAY

various coal operations on the grade west of the Elkhorn tunnel, or these empty trains may at times be run through to Eckman or Vivian. East bound trains average about 45 loaded cars each up the Elkhorn grade and may be filled out to 50 loaded cars at Flat Top. Standard west bound trains consist of about 65 cars of empties, but lighter trains are run as occasion demands. Loaded trains are sometimes run west from Flat Top and these consist of about 45 loaded cars, or 3 250 tons.

Speed of Trains—Trains of 3 250 tons are to be operated at a normal running speed of approximately 14 miles per hour up grades of from one to two percent and at a normal running speed of approximately 28 miles per hour on level track and existing main line grades up to 0.4 percent. The normal running speed down grades of 1 to 2.5 percent will be approximately 15 miles per hour when holding the train by regeneration.

Method of Operation—Two single electric locomotives will form one road unit, making the round trip runs between Bluefield and either Vivian, Eckman or North Fork, as required, handling empty cars on the west bound trip and loaded cars on the east bound trip.

Two locomotives coupled and operated together will form one pusher unit and will make round trips between Ruth and Vivian. Eckman or North Fork. On the west bound trip the pusher unit will be coupled to the rear of the train and will be used as a switcher to distribute empties as required on the grade. On the east bound trip the pusher unit, operating at the rear end of the train, will also be used as a switcher to pick up loaded cars at the various stops on the grade. The tractive efforts exerted under the various operating conditions are given in Table I.

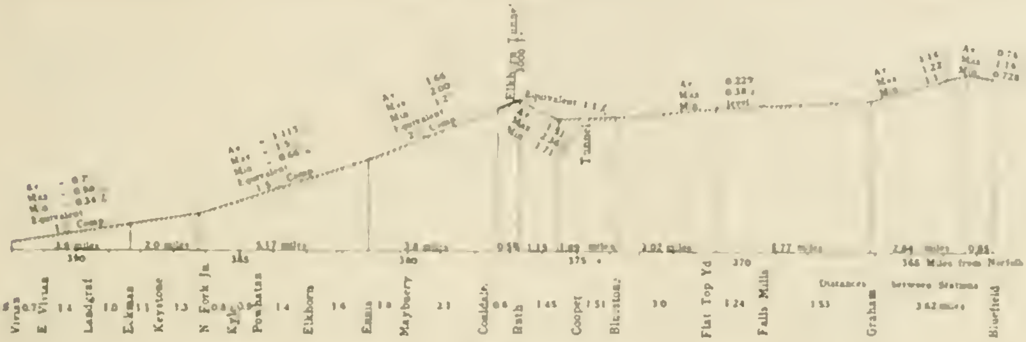


FIG. 2—PROFILE OF LINE—VIVIAN TO BLUEFIELD

Power House Equipment—The power house will be located at Bluestone, the equipment consisting of three 9 000 kilowatt, single-phase, 25 cycle, 11 000 volt, 1 500 r.p.m. turbo-generator units, with two turbo-exciters, and a motor-generator exciter set, together with step-up transformers for 33 000 volt transmission lines to feed the transformer sub-stations.

TABLE I—TRACTIVE EFFORTS FOR DIFFERENT GRADES AND LOADS

	Train on 1.5 and 2 percent grades	Train on 1 percent grades	Train on 1.22 percent grades	Train on 0.4 percent grades
Weight of train—tons	3 250	3 250	3 500	3 250
Locomotives per train	4	2	3	2
Approximate speed, miles per hour	14	14	14	28
Draw-bar pull per locomotive, lbs.				
Uniform Acceleration	45 900	57 000	47 700	39 700
On 2 percent grade	37 700	....	....	....
" 1 " "	....	42 900	....	....
" 1.22 percent grade	....	....	36 000	....
" 0.4 " "	....	....	....	23 000
Maximum accelerating tractive effort per locomotive, lbs.	62 500	62 500	62 500	45 000

TYPE OF LOCOMOTIVE

The locomotives, of Baldwin-Westinghouse make, have articulated trucks and weigh 130 tons each. As shown in Fig. 3, four driving axles and two carrying axles are used, the wheel base being divided into two separate units or trucks, connected at adjacent ends by a hinge coupling. The carrying axles are mounted radially and each main truck has two driving axles and one radial axle. The outer ends of the trucks are fitted with standard buffers and friction draft gear with standard coupler, the draw-bar pull being transmitted through the truck frames to the train. The weight does not exceed 57 000 lbs. per pair of drivers and is sufficient to produce a tractive adhesion for a maximum effort of 62 500 lbs. per locomotive; the weight on each radial axle is not less than 20 000 lbs. at the rail. The locomotive will, with forced ventilation, have sufficient capacity to exert continuously a tractive effort of 33 600 lbs.

A single cab supported on the trucks at suitable bearing points, contains the operating and control apparatus of the locomotive. The cab is of the box form, provided with end doors and platforms for convenient passage between two or more locomotives when coupled together, and between the locomotive and train; in addition, side doors are provided at diagonally opposite corners. There are also side and end windows for lighting the cab. The apparatus is arranged along the center of the cab, making it conveniently accessible and leaving a clear, unobstructed passageway at either side.

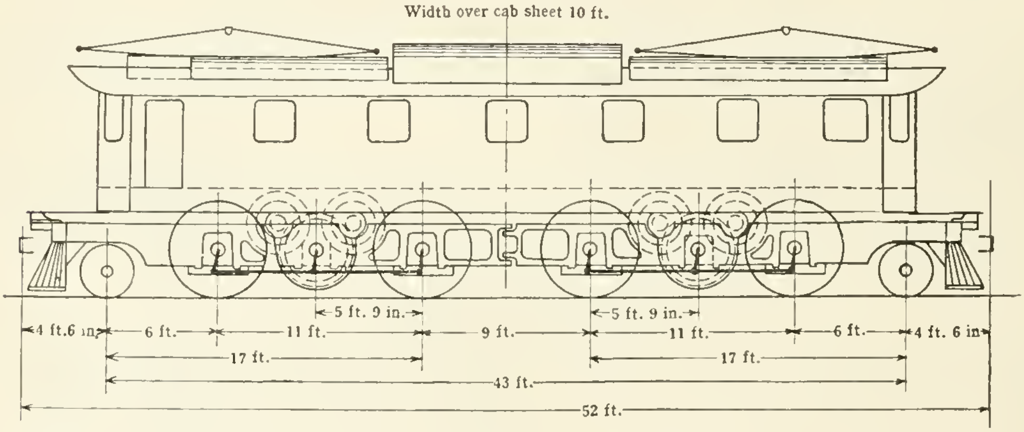


FIG. 3—OUTLINE SKETCH OF NORFOLK AND WESTERN ELECTRIC LOCOMOTIVE

The control apparatus, both air and electric, is located at one end of the cab, in such a manner as to leave an unobstructed view along the track. The operator's seat is located so that there will be a clear view of the signals.

Each locomotive is provided with two overhead pantagraph trolleys having automatic self-adjusting action and arranged for a working height of 16 feet under bridges or other permanent structures and a normal height of 24 feet along the open line, the trolleys being controlled by air pressure. Current is taken from the trolley at a normal potential of 11 000 volts. The present plans cover the purchase of 24 locomotives.

Motor Equipment—The motors, which are connected through twin gearing to a jack shaft, are of the polyphase, 25-cycle induction type with wound secondaries, which are connected in cascade for producing low speed in starting and switching. There are two running speeds, 28 and 14 miles per hour, and a switching speed of seven miles per hour. In starting with the seven-mile combination, the motors on each truck will be connected in cascade and the two sets of cascades will be connected in parallel. Resistance will be inserted in the secondaries at starting. In this combination the primaries will be arranged for eight poles. With the 14-mile combination all motors will be in parallel connected for eight poles, and with the 28-mile combination a four-pole arrangement will be used, resistance being used on intermediate steps.

Control Apparatus—A multiple-unit system of control is to be provided for the independent operation of each locomotive, or for the operation of two units simultaneously from the control end of either locomotive in whatever order or arrangement the locomotive may be coupled together. The control equipment is arranged and constructed to provide for the use of single-phase current from the pantagraph trolley which is connected to the primary winding of the main transformer through a suitable line switch; from the secondary of the transformer, circuits will be established through and in connection with the phase converter in such a manner as to deliver polyphase current to the main motors.

Each locomotive is provided with an air compressor driven from the phase converter, through a multiple-disc friction clutch. This clutch is controlled by the main reservoir pressure so that the compressor is operated only as required. Each locomotive is equipped with straight air and automatic air brakes, and is also provided with the necessary ventilating apparatus for the motor equipment, transformers, etc., together with sander and cab heating equipment.

The electrical equipment has been designed with special consideration for regeneration and electric braking on grades, both for the purpose of safety and economy of operation, the latter features resulting in a reduction in the demand on the generating system, as well as a decrease in the wear and tear on the train equipment, the local conditions being very favorable for this type of operation.

WHY STEAM RAILROADS ARE ELECTRIFYING

W. R. STINEMETZ

THE growth of the electric system in the transportation field has been a gradual development, not of the motor or equipment alone, but of the entire apparatus for transforming power from the coal pile or water wheel to the axle of the locomotive or car. There is no one reason for the gradual invasion of the steam locomotive domain. Every advance has been due to the ability of the electric system to meet some particular condition more successfully than its rival. The present increased activity in the application of the electric locomotive to steam railroad properties is due, first, to the fact that electrical apparatus has demonstrated its ability to handle large quantities of power reliably and economically while its flexibility makes possible the delivery of this power, where needed, in the most advantageous manner; second, because the operating conditions and traffic demands on steam railroads have increased at such a rate that the steam locomotive in spite of its recent development is, in many cases, no longer able to meet those conditions successfully.

TERMINALS

The first inroad of the electric system was on the elevated railways of large cities where the steam engine has been entirely eliminated. This was due to its ability to start long trains quickly and efficiently; its flexibility which, with the multiple-unit system, permits the size of trains to be regulated as the immediate traffic demands, and its availability for service at all times without advance preparation. A considerable saving in trackage in the terminals is effected by the fact that there is no turning or shifting to be done, nor is there the necessity for frequent trips to the round house for inspecting and hostlering. The excellent showing made on the elevated roads soon lead to the adoption of the electric system in the large terminals of steam roads having heavy suburban traffic.

It has been stated that the speed of trains on suburban traffic has been increased 40 percent, due to electrification, also that double the number of trains can be handled in the terminals with the same trackage as was required by steam operation.

TUNNELS

The next surrender of the steam to electric operation was in tunnel work. This is shown in the various subways and tunnels which have been electrified, such as those in New York, the Hoosac and the St. Clair Tunnels, the Baltimore & Ohio, the Detroit River and the Northern Pacific Cascade Tunnels. In this class of work, not only has the great danger due to smoke and gases, together with the inability to see signals in the tunnel, been eliminated, but the delays to traffic while waiting for these fumes to be cleared has been overcome. This feature has, under unfavorable atmospheric conditions, compelled trains under steam operation to wait for an hour before entering, thus causing a congestion of traffic.

For these reasons the electrification of the Hoosac Tunnel quadrupled its capacity for handling traffic. In the Cascade Tunnel, due to its length and grade, it was necessary to hold the trains until the fires of the Mallet engines could be drawn and new ones built with high grade coal before entering.

As these tunnel divisions are often the limiting portions of the road, their capacity determines the amount of traffic which can be handled; consequently the elimination of this congested section by electrification enlarges the traffic capacity of the entire road. Furthermore, electrification has, as regards passenger service, transformed the dirty and disagreeable tunnel trip with the steam locomotives to a cleanly and cheerful experience which greatly enhances the popularity of the road with the traveling public.

GRADES

The third place where the attack is now centered is in freight haulage on mountain divisions. Not many years ago the electrification of trunk line steam railroads was considered impracticable, but the steam engineers were following the development of the electric systems with their approaching possibilities. This gave them a great incentive for development and led to marked improvements in the steam locomotive, in order to meet the new conditions of traffic. Notwithstanding this, however, there is a growing demand by steam railroad men for advice on the cost, economy, depreciation and maintenance of electric locomotives for certain conditions of service.

As 70 percent of the revenue derived from the operation of railroads is obtained from the transportation of freight, economies effected on these mountain divisions, where the cost is high, will have a large bearing on the total net revenue. Furthermore, in many cases the congestion of traffic which it is impossible to relieve by additional trackage, due to physical characteristics, demands relief in more speed and heavier trains.

LOCOMOTIVE DEVELOPMENT

The Mallet engine is the latest development of steam engineers to meet the requirements of this class of work. This engine is built to the maximum size as regards road clearances, with a view to replacing two consolidation type engines, with resultant economy. Its advantages as shown by test are as follows:—

Compared with two consolidation type engines of equal capacity, and with the total weight including the tenders the same, the Mallet has 20 to 25 percent more weight available for adhesion, due to a better distribution of this weight, which increases its ability to start heavy trains. Tests have shown that, by the use of the superheater, compound cylinders and brick arches, a saving in coal and water consumption of from 35 to 40 percent is effected for each 1 000 ton miles at practically the same speed. With its mechanical stoker and power operated reverse gear and scoops, the Mallet saves the wages of one engineer and fireman, as compared with the two consolidation engines.

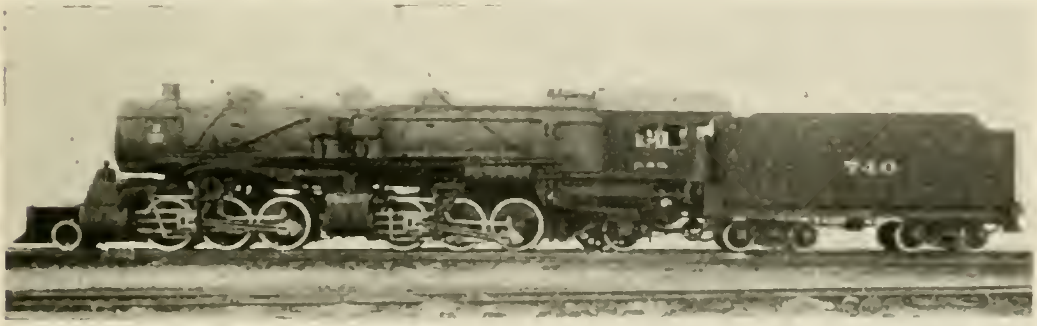
TABLE I—DATA ON MALLET AND ELECTRIC LOCOMOTIVES

Characteristics	Mallet 2-6-6-2	Electric 2-8-8-2
Total wheel base Engine and tender ft.	81	83
Rigid wheel base, ft.	10	11
Weight, engine and tender, lbs.	550 000	430 000
Weight engine only, lbs.	378 650	430 000
Weight engine on drivers, lbs.	325 850	380 000
Number pairs of drivers	6	8
Weight on pair of drivers, lbs.	54 300	47 500
Steam or voltage, lbs. or volts	200	11 000
Wheel diameter, inches	54	62
Maximum tractive effort, lbs.	77 400	102 600
Continuous " " "	54 500	54 500
Speed, miles, per hour	10.8	17.5
One hour rating, tractive effort, lbs.	54 500	70 500

It should be noted that the electric engine develops the same continuous effort at 60 percent higher speed than the Mallet and herefore is of 60 percent greater continuous horse-power.

Capacity—The principal characteristics of a Mallet and an electric engine of the same continuous tractive power, suitable for use in grade work are given in Table I. The largest Mallet built weighs 752 000 pounds with an axle loading of 60 000 pounds on each pair of drivers, and a maximum tractive effort of 115 000 pounds at slow speed. The Mallet chosen above, however, is the size in most common use and for which there is reliable performance data available. The figures given were taken from a series of full service capacity tests in hauling a 3 513 ton train up a ½ percent grade, a distance of 22 miles, which required 202 lbs. of coal and 1 230 lbs. of water, per 1 000 ton-miles of load.

Although the electric locomotive given in comparison has the same continuous tractive power and 60 percent greater horse-power, it shows a saving in weight of 120 000 lbs. and has 6 800 lbs. less weight per driving axle, which features would result in considerably less injury to the track and road bed. The injury to the track caused by heavy Mallets is becoming a source of serious concern to railroad men. Coupled with these advantages, the capacity of the electric locomotive for hauling loads in mountain work is much greater than the Mallet, even at the higher speed shown. For example, assume these locomotives in service on a two percent grade, which is the controlling factor of an electrified division, the remainder of which has a fairly level profile. On this grade the Mallet engine alone requires a tractive effort of 16 500 lbs., leaving an available draw-bar pull of 38 000 lbs. or a tonnage capacity of 880 tons. At a speed of 10.8 miles per hour, it would take 67 minutes of continuous running to cover the 12 miles. The electric locomotive, using only 11 800 lbs. tractive effort to propel itself, would have remaining 58 700 lbs. draw-bar pull, or a tonnage capacity of 1 360 tons, which at 17.3 miles per hour requires only 42 minutes to make the trip.



MODERN 2-6-6-2 TYPE MALLET LOCOMOTIVE.

Thus it is evident that the electric locomotive can develop $\frac{58700 \times 17.3}{375} = 2700$ draw-bar horse-power as against $\frac{38000 \times 10.8}{375}$ 1 095 drawbar horse-power of the Mallet, or an increase of 146 percent over the steam engine in this service. In other words, two electric locomotives could handle the same load as three Mallets, with a saving in running time alone of 37.5 percent. This great superiority in horse-power load capacity is due, first, to the fact that the electric locomotive carries very little excess weight above that necesary for adhesion, while the extra weight of the Mallet represents 6.8 percent of its total trailing tonnage; second, that the electric locomotive is able to concentrate more power capacity in equal space and weight, permitting the same tractive effort at a higher speed; third, the Mallet is limited by its steaming power and has no overload capacity, while the electric locomotive is only limited by the overload capacity of its motors and, in the comparison above, these can be worked at their one-hour rating which is an increase in tractive effort of 29 percent over the continuous rating of either locomotive.

Maintenance—The following record, showing the average of a number of Mallet locomotives after having been in mountain service for two years, is a good example of the cost of maintaining such engines:—

TEN-CAR PASSENGER TRAIN ON A HEAVY GRADE.
Four locomotives pulling and one pushing

Total yearly mileage	26 745
" " repairs, dollars	5 757
" " supplies, dollars	481
" " roundhouse expense, dollars	653
" days in shop for repairs	89
Average daily mileage	73. 4
" " " when running	97. 0
Repairs per locomotive mile, cents	21. 6
Supplies " " " "	1.82
Roundhouse per locomotive mile, cents	2.43

These same records show that one-half of the cost of repairs is centered in the boilers, which expense is eliminated in the electric locomotive. A further saving of at least 40 percent in the round house expense and supplies is effected with the electric locomotive, as there are no ash pits, fire boxes and boilers to clean and the turning of the locomotives is unnecessary. Therefore, assuming the cost of mechanical repairs the same in both engines, and applying the saving in roundhouse expense noted above, to the cost of electrical repairs only, the maintenance of the electric locomotive would average about 55 percent of that of the steam or 14.32 cents against 25.85 cents per locomotive-mile. This ratio is verified by records of steam roads operating electric sections in other classes of service; for example, the cost of maintenance of the electric locomotives on the Pennsylvania Railroad is given as 6.74 cents per locomotive-mile, while the cost of maintenance of the steam locomotives on all divisions is 14.72 cents.

Speed and Revenue Miles—The great difference between the steam and electric locomotives for grade work, however, is in the saving of time, not only as regards a higher running speed, but also in delays due to taking water and coal, and returning to the ash pit periodically. The Mallet, being a self-contained unit with its own coal and water supply, can furnish steam only in limited quantities. Its best operation is at a speed of about 10 miles per hour and this cannot be exceeded without a reduction in the drawbar pull. The electric locomotive drawing energy from a large power house is able to furnish the same drawbar pull at much higher speeds continually, as it does not have to generate in itself the energy for propelling the train nor is it necessary to stop at intervals to renew fuel supplies.

ELECTRIC ENGINE PULLING STEAM ENGINE AND FREIGHT TRAIN AT TUNNEL OF THE BOSTON & MAINE RAILROAD

Records for a grade section of a mountain road show that out of a total schedule time of 6 hours, 38 minutes, the delays for coal and water amounted to 59 minutes, or 14.5 percent of the total time. On another road in the same class of work, the total time consumed in performing a certain operation or cycle of work was 6 hours, 56 minutes, averaged from many trips. Of this time, one hour, 58 minutes, or 28.4 percent was consumed in going to the ash pit, attention at the pit and returning to the siding. For these reasons and its higher speed the electric locomotive can double the schedule, which means doubling the track capacity.

MAIN LINE

In all the cases cited where the electric system has supplanted the steam locomotive, there has been some vital feature of operation, which has been improved by this substitution. This change has not been made primarily for economic reasons. The electrification of a steam property is an expensive undertaking, and in very few cases would the savings effected in operating costs only justify the expenditure. There are, however, some interesting features on the mountain divisions of Western roads which are causing the managements of these properties to study the application of the electric locomotive for main line operation from the standpoint of economy alone.

The quality of coal obtained is much inferior and the cost is in excess of that in the East. The problem of getting good water distribution along the line is a very serious and expensive one. The severe cold weather conditions greatly reduces the steaming power and economy of the steam locomotive, when it requires its maximum power, due to snow and increased train resistance.

On the other hand, large water power plants are in operation or contemplated in convenient locations, with enormous power available to the railroad companies at low rates. This reduces the initial investment required by about one-fourth to one-third below that for a road building its own power house, and from an operating standpoint leaves only the sub-stations, line and the locomotives to be cared for.

But aside from this, when one looks back at the steady advance and development of the electric system and sees how it has met and fulfilled each demand, reliably and economically, it is only reasonable to believe that, when the great roads of the East have their terminals, tunnels and grades electrified, the natural step will be to connect these sections of the main line and abandon the steam locomotives entirely. And when this time arrives there is no doubt but that the electrical development will be such as to meet these conditions without difficulty.

LOS ANGELES CENTER ENTRANCE CARS

E. L. STEPHENS,
Master Mechanic
Los Angeles Railway Company

THE Los Angeles Railway Company after considerable experimenting during the past year has developed a typical California-type center entrance car. This has been done by remodelling cars of their older types. In the reconstruction of the old cars several new features have been brought out, some of which might be termed object lessons, chief among which is that no special motors, air brakes, trucks or wheels are required in making the changes, and the entire equipment remains the common standard which has been adopted for the entire system.

Several cars were rebuilt and tested out in regular service and, after a few minor changes, a design was settled upon which is believed to meet the conditions of service and climate most satisfactorily. The new cars seem to have made a favorable impression on all electric railway men who have insepected them and also those from other sections of the country who have made any inquiries and received information regarding the details of design of the car. Fifteen of the rebuilt cars are now in regular service, and are meeting with the approval of both the traveling public of Los Angeles and the motormen and conductors handling the cars.

The method used in remodelling these cars differs somewhat from the general practice. Instead of making additions to the ends of the car, the car was cut in two and a "P. A. Y. E." section 7 feet 6 inches in length was spliced in the center. It was realized that it was impractical to adopt a stepless car owing to the many hills, and in order to maintain the present standard equipment it was found advisable to adopt a single step with a double sloping floor.

First, the upper deck is removed, the deck sash taken out, the roof lowered to the deck sill, and by applying false rafters from the top plate to the deck sills, which are strengthened by iron carlines, the car roof is changed to the monitor type, thus making possible the use of the old head lining, which would otherwise have been discarded. The entire floor framing is removed from the car, the body posts are spliced out to fit the slope of the floor, and most of the framing is used over again in the new floor, which is of I-beam constructions, consisting of two 5-inch, 14¾ lbs. I-beams for the side sills and two 4-inch, 10½ lbs. center I-beams. The center beams are bolted close together because of the floor height, 37½ inches, and for the reason that the wheels must curve between the side and center beams and sufficient space be allowed for a fluctuating load, also to provide sufficient room for the standard truck with a 5-foot 3-inch wheel base with 30-inch wheels to curve on a 42-foot radius.

The side beams are shaped to permit a recess at the center for a 10-inch step which is flush with the car body, and these beams are filled with wood fillers to which the floor nailings girts are morticed.

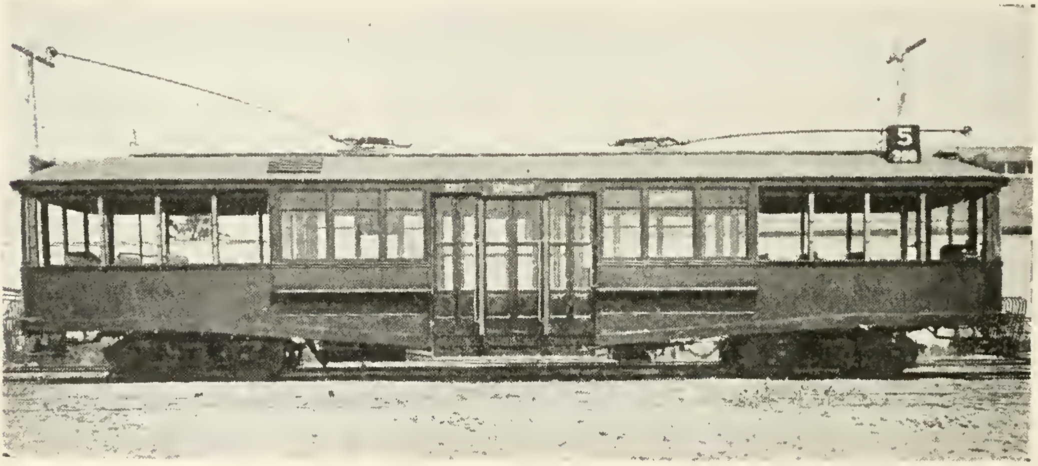


FIG. 1—LOS ANGELES CENTER ENTRANCE CAR AS RECONSTRUCTED.

The floor has a double slope, one a side slope from the side beams to the center, and the other a slope from the entrance to the bolsters. A side slope of 1½ inch is made in the 4-inch I-beams at the center of the car in order to allow clearance for the brake connecting rods between the trucks.

The cars are divided into two open and a closed section. The closed sections have longitudinal seats which slope 1¼ inches in 6 feet to relieve the variation caused by the sloping of the floor. In the entrance section are four stanchions extending from the floor to the roof. To one of these is attached a fare box and an adjustable conductor's seat. Between each two of these stanchions is provided a removable bar which serves as a barrier and which can be transferred from one side to the other, permitting the conductor to stand behind the fare box and entirely out of the way of the passengers. Swinging doors control the entrance and exit with two doors to each space which are operated by a series of levers under the car. All movable parts of the door are on ball-bearings and the freedom of movement is such that a five-inch handle is all that is required to operate the doors simultaneously.

The open sections are at either end of the car. In each of the open sections are seven "walkover" and one stationary seat. The motorman occupies a space in the corner protected by a pipe barrier. To the stanchion, which forms a part of the motorman's barrier, is attached an adjustable seat and also a curtain to shield him from the car lighting.

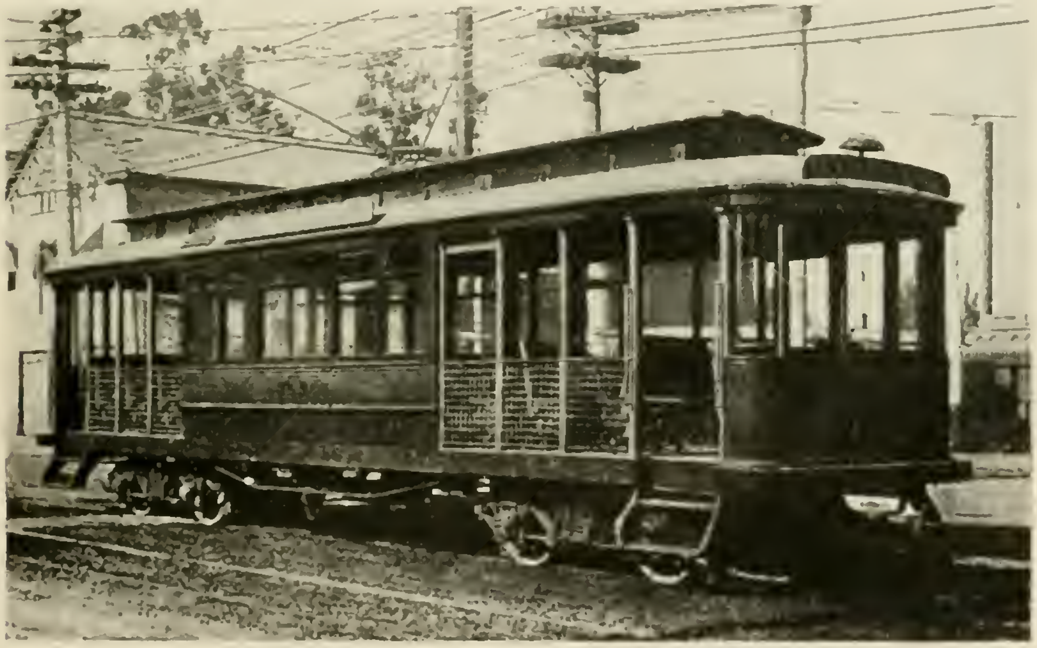


FIG. 2—ONE OF THE OLD TYPE CARS BEFORE REMODELLING.

The open and closed sections are separated by bulk heads, each having a single door with side sash. Push buttons are provided in all body posts and all signals are controlled by the conductor.

The principal dimensions and details of the new type cars are as follows:—

Length over buffers	46 ft.	7 in.
Width over all	8 ft.	5 in.
Length each open section	12 ft.	2¾ in
Length each closed section	7 ft.	3¾ in.
Length entrance section	7 ft.	6 in
Truck centers	30 ft.	6 in.
Truck wheel base	5 ft.	3 in.
Diameter of wheels		30 in.
Total height	11 ft.	3¼ in
Seating capacity	54	
Weight complete, lbs	37,000	

The trucks used on these cars are known as the Los Angeles Railway diamond frame. Every part of these trucks is held in position by bolts properly proportioned for strength. This makes it possible to maintain a noiseless truck. Ball-bearing center plates are used exclusively. Brake adjustments are taken care of by a single nut on each truck.

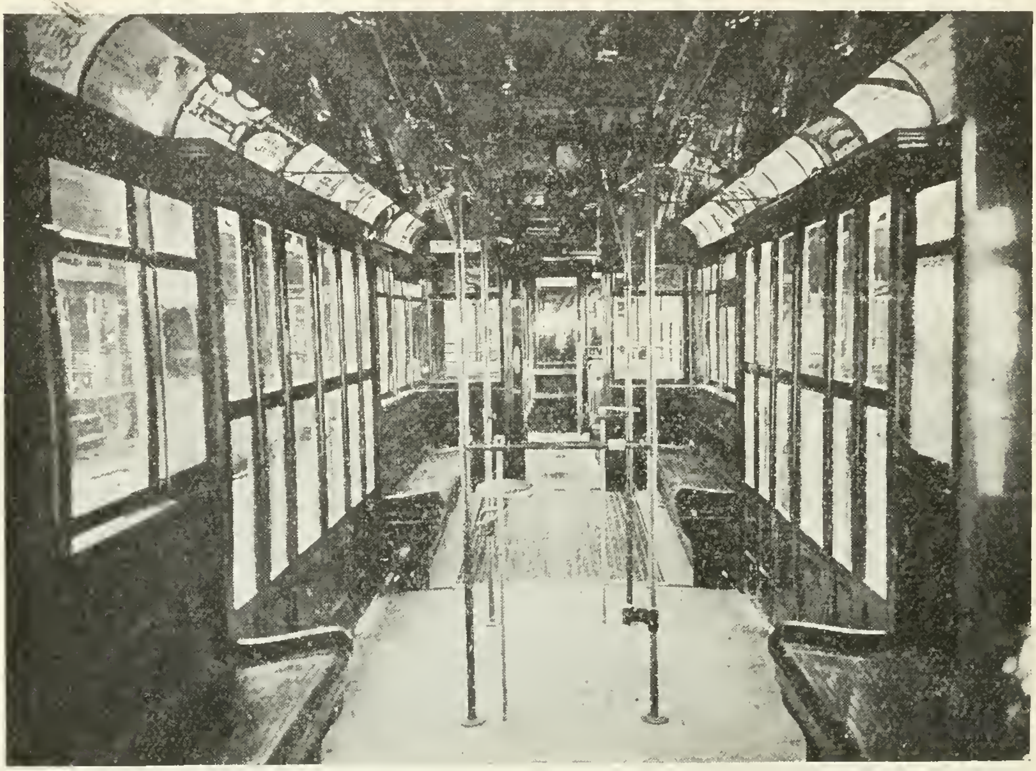


FIG. 3—INTERIOR VIEW OF REMODELED CAR

By reconstructing the old type car to the center entrance type the seating capacity has been increased from 44 to 54 persons, and the total weight of the car has been reduced 500 pounds.

TRAIN OPERATION IN CITY SERVICE

F. M. LOUD
Public Service Railway Company, Newark, N. J.

THE city of Newark, New Jersey, presents an unusually perplexing problem to those who are trying to supply its traffic needs. A single glance at the map shows how the city has grown up around a group of radiating thoroughfares which were originally the country roads from the little town of Newark to other villages around it. As population increased the intervening spaces have been built up, but the old highways have been kept as the principal streets ,and the whole territory has retained a focal point at the interesction of Broad and Market streets, still known as the "Four Corners." As one result there are sixteen car lines which come within a block of this intersection. During the busiest hour in the evening 520 cars pass over this crossing, and any one who stands and watches the traffic must admit that there are good grounds for its reputation as the "second businest corner in the United States."

This congestion was one of the problems which set the officials of the Public Service Railway to thinking about the possibility of two-car train operation in city service. In order to obtain data on the feasibility of such operation a test was conducted on the six lines which are shown prominently in Fig. 1, and a large number of observations were made of the number and length of stops, adherence to schedule running time, time required for passenger movement and other matters, both for trains and for single cars. At the same time a comparison was made between multiple-unit operation and trailer operation, several different combinations of multiple-unit trains being used, namely two four-motor cars, two two-motor cars, and a four-motor car with a two-motor car. A large amount of data was obtained, much of which was also of local interest and value aside from the question of train operation, as showing the distribution of traffic over the different parts of each line.

The four-motor cars used in the test were of the type shown in Fig. 3. They were equipped with commutating pole motors with hand operated unit-switch control. The air brake equipment was a straight-air system, with quick service valves and emergency feature. Radial couplers were used, the air connections between the two cars being made automatically in the couplers. The two-motor cars had somewhat lighter bodies, and were similarly equipped, the motors having the additional feature of field control.

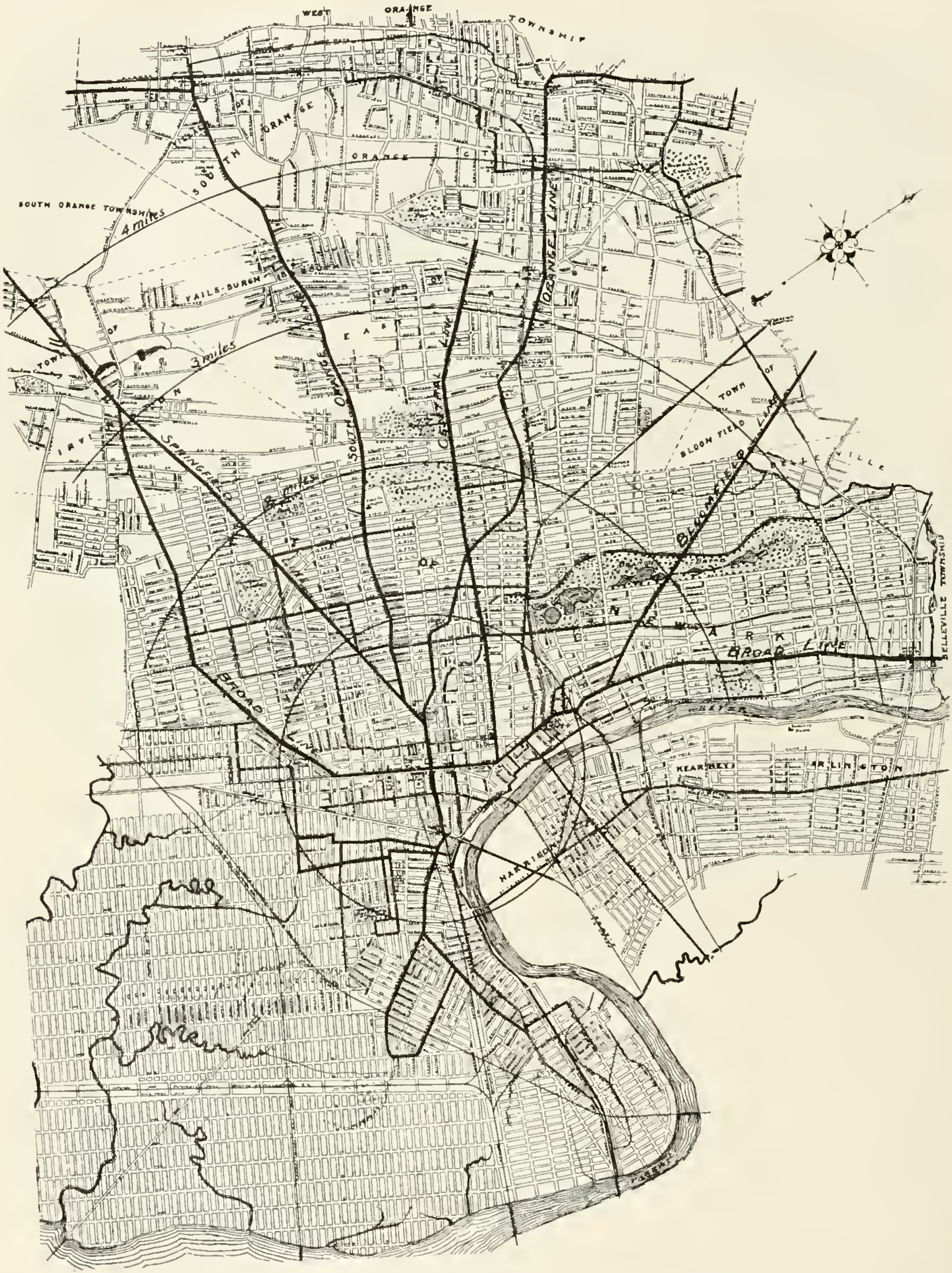


FIG. 1—MAP OF NEWARK, N. J., AND SUBURBS

In comparing the various type of trains that were tested, that made up of two four-motor cars gave the best results, as might be expected. However, the six-motor train, made up of a four-motor car and a two-motor car, was a close second. The adherence to schedule was almost as good and could probably be made quite as good with a slightly different motor equipment on the two-motor car. This combination recommends itself on account of the power saving as compared with an eight-motor train, and on account of the possibility on some lines of using the two-motor cars alone during the hours of light travel and under good weather conditions. This would mean a further saving in power consumption, while the four-motor cars would be available for use when rail or traffic conditions made it desirable.

The four-motor trains with two motors on each car, or with four motors on one car and none on the other, did not appear to be very satisfactory for Newark conditions. The trailer combination, particularly, showed many disadvantages. On account of its slower acceleration and reduced running speed, it lost time badly on most of the test runs. In order to maintain schedule it would be necessary to use motors of greater capacity, which would then be larger than would be suitable for the single-car operation in the middle of the day. Smaller motors, besides causing delay, would themselves be injured by the frequent overloads.

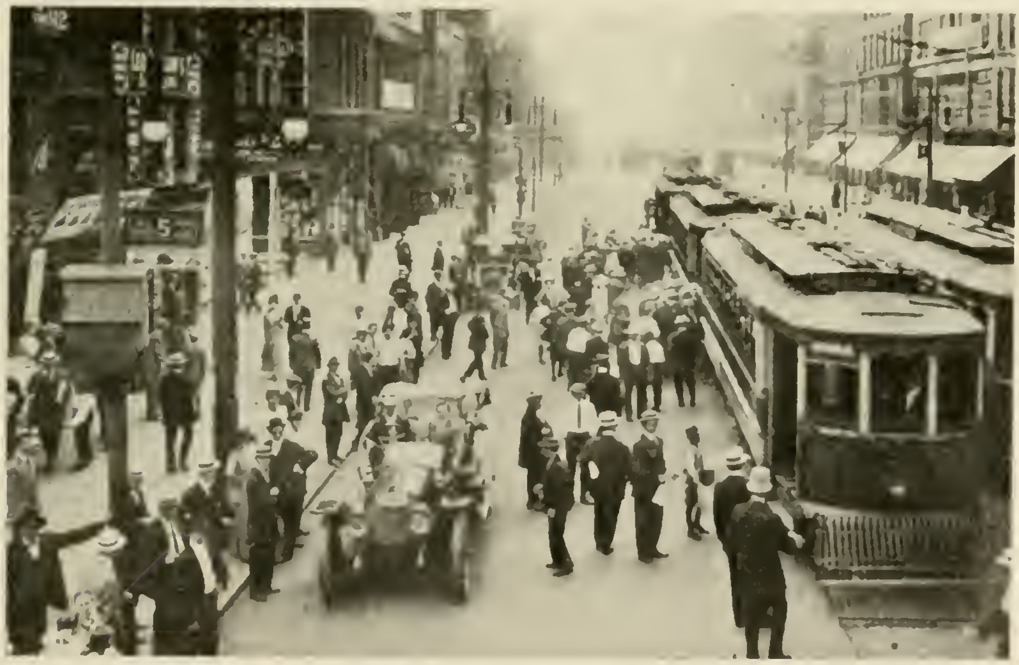


FIG. 2—VIEW AT BROAD AND MARKET STREETS SHOWING TWO-CAR TRAINS

The city operating man finds many other difficulties in handling cars without motors. He must always run them *behind* the motor cars, for reasons of safety and on account of the short curves. This necessitates loops or wyes at the ends of the line to avoid switching and coupling delays, and also means that he cannot turn cars back in case of delay along the line, except at points where he can turn them around. In case the motor car becomes crippled, the presence of the dead trailer makes the situation more difficult to handle, and increases the time lost, and the possibility of a "tie-up." These cars increase the amount and the danger of shifting at the car house. They are of no use except for certain service at certain hours. These difficulties largely disappear when all cars are equipped with motors and multiple-unit control. The greater flexibility and more satisfactory performance of the latter arrangement more than offsets any saving in investment which is gained by the use of trailers.

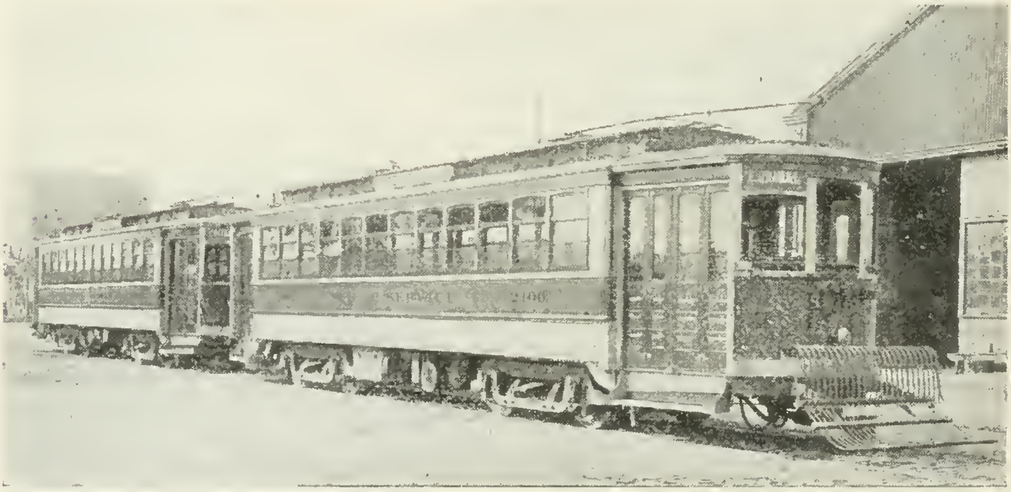


FIG. 3—TWO-CAR TRAINS
Four motors per car.

One of the main points to be considered in determining the feasibility of train operation is the question of running time; i. e., whether the trains can get from one end of the line to the other as quickly as the single cars and at the same time carry their proportionate share of passengers. This is essential, if both trains and single units are to be operated at the same time, so that there will be no interference. Even if the entire line is run in trains, it is desirable to keep the same running time as with single cars, as a slower schedule requires more cars and increased platform expenses and is not so satisfactory to the public.

It was found during the test that the trains made up of two four-motor cars were able, in general, to maintain practically the same running time as the single cars. The train made a little better time through the congested district between the Pennsylvania Station and the corner of Washington and Central avenues, while from the latter point on it made about the same average speed as the single car.

There are four factors which determine the relative running time of different equipments:—viz., the number of stops, the length of stop, the rate of acceleration, and the running speed. There is very little difference in the last two items between a single four-motor car and a train of two such cars. If anything, the train has a slight advantage on account of decreased interference from other traffic, and because of diminished train resistance in proportion to motor capacity. In snow or sleet storms or at other times when rail conditions are bad, the train has a decided advantage. The first car removes sleet, snow, etc., leaving a good rail for the second car. This fact has been used to good advantage in several snow storms.

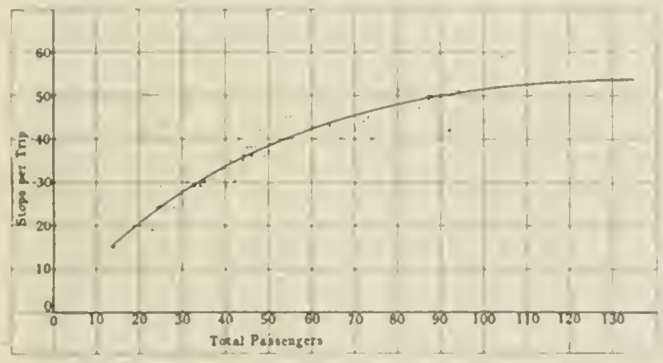


FIG. 4—CURVE SHOWING STOPS PER PASSENGER

The number of stops bears a definite relation on any particular line, to the total number of passengers carried. For a given number of passengers it makes no difference whether they are carried in one car or two. A train, however, will normally carry more people than a single car and will have to make a few more stops, but the increase is not nearly as great as might be expected. A curve was worked out for the Central Line, Fig. 4, and a continuation of this curve, together with the original data, shows only three more stops required for 150 passengers than for 100, and only four more when the total number carried is 200. The explanation of this is, of course, that beyond a certain point an increase in the number of passengers carried results in more of them getting on or off at each stop rather than in a greater number of stops. This point is reached most quickly on a line which is comparatively short and which runs through densely populated territory. It would seem, then, that such a line would be best suited for the use of trains. This relation suggests also the advantage of the plan of stopping only at alternate streets, or in the middle of alternate blocks, thus concentrating the passenger movement at a smaller number of stopping points.

The length of stop is a factor which depends on many variables; e. i., the habits of the people, whether they "step lively" or are slow in getting on or off, the number of small children or large bundles they take with them, the design and location of the entrances and exits of the car, the alertness and "team work" of the crew in getting started promptly, the judgment of the motorman in stopping his train at the right place. It is in improving such matters as these that most can be accomplished in improving the performance of trains. The passengers can be educated to be near the proper exit when approaching their stop, and to move promptly when entering or leaving the car. Conductors can be trained to avoid wasting time in handling the doors and in passing bell-signals. Motormen can learn to start the train promptly, to operate it with as much confidence as they would have in running a single car, and to make smooth, clean-cut stops in such a way that passengers will not hesitate in choosing which car to board or will not have to walk half a car-length to reach the entrance.

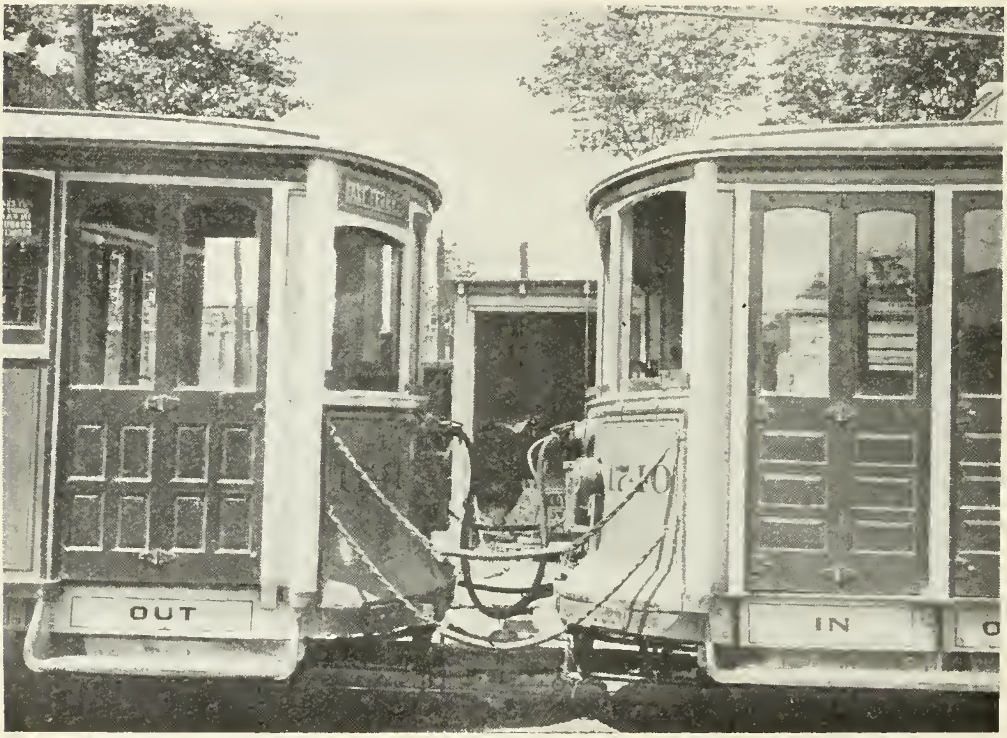


FIG 5—VIEW SHOWING JUMPERS IN PLACE AND GUARD CHAINS

The cars used in the test were of the prepayment type with separated entrance and exit on the rear platform and a wide exit at the front end. In the second car of a train, the rear platform only was used, making it necessary for all passengers in that car to leave by the narrow exit at that end. This caused some loss of time both on account of the greater number of people to be passed through the exit and also because passengers would often start for the front door and then have to go back through the car. Under these conditions the average length of stop was less for a train than for a single car, when the total number of passengers was the same, but for equal loads per car, the train required slightly longer stops. If a center-entrance type of car were used, where the entrances and exits are under the control of one man, or if an arrangement could be devised by which the conductor on the front car could operate the front doors of the second car to let people off without letting others on, this condition would probably be much improved. If but one platform of the second car is to be used, better results might be obtained by using the front one, as this would bring the two entrances together and passengers would board more quickly, distributing themselves more evenly between the two cars. By giving attention to matters of this sort, the average stop for a train can probably be made fully as short as that for a single car with the same proportionate load. As the number of stops made by a train is only slightly larger than the number made by the single car, this leads to the conclusion that the train under proper conditions will make very nearly as good running time as the separate unit. The test observations made seemed to bear out this conclusion.

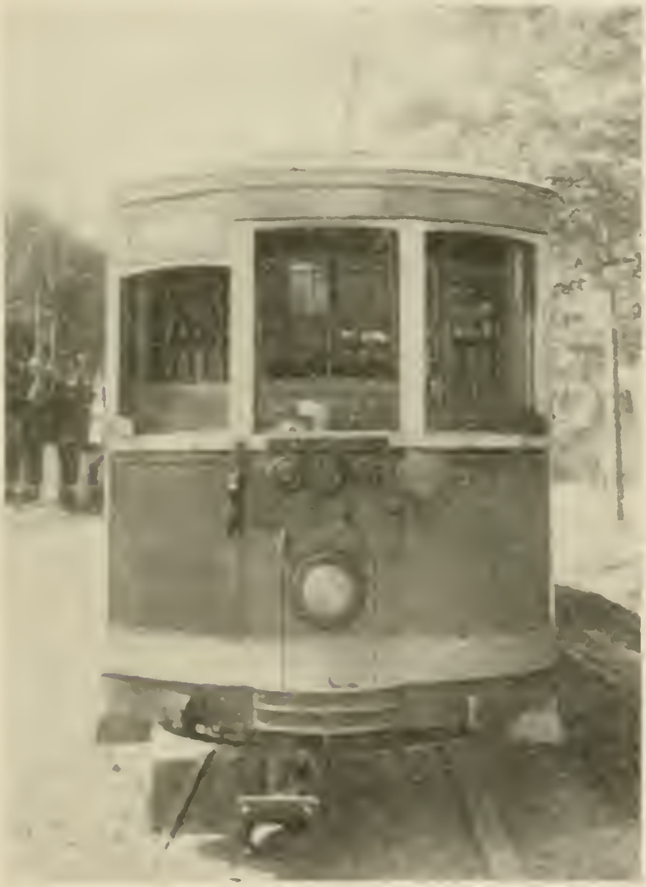


FIG. 6—VIEW SHOWING LOCATION OF TRAIN, BUS AND SIGNAL LINE RECEPTACLES

It is reasonable to presume that train operation, if practicable, will aid in relieving congestion. For one thing it does away with the space between two cars. This means an increase of track capacity, only slight for standing cars, but very considerable for a line of moving cars, as with single units each motorman must keep a safe distance back from the car ahead. This closing together of the cars also affects the time required to pass them across a busy street, as at Broad and Market. Observations indicate that a two-car train will clear a crossing in about 80 percent of the time required for two single cars. The saving of time at this particular corner means increased capacity at the rush hour, which affects all lines crossing this point, also a train will meet with less interference from vehicular traffic than two independent units.

Multiple-unit operation also offers the alternative possibilities of reducing platform expenses, or of providing additional service without additional platform cost. Suppose a line has been operated with thirty cars, requiring sixty men. The same number of cars can be run in fifteen trains with forty-five men, the headway being twice what it was with single cars. Or, with the same number of men, twenty trains (40 cars) could be run, giving 33 percent increase in capacity and lengthening the headway 50 percent. Local conditions must determine whether either of these courses or an intermediate one should be followed. Unless the headway with single cars is quite short there is likely to be objection from patrons to having it lengthened, except when they can see an advantage in more seating capacity.

There are some places in which the possibility is suggested of running two cars in train through the district of heavy loading, then letting one car go on to the end of the line through the district where travel is light while the other car is attached to the next inbound car and goes back for another load. This seems attractive and may be feasible under certain conditions, if the processes of coupling and uncoupling can be simplified and systematized.

One type of service in which trains have been found most useful is in carrying large crowds from ball games and races. These people all wish to travel at about the same time and it is desirable to run cars as closely together as they can be operated safely. Under such conditions the full economy of multiple-unit operation can be realized.

THE AUTOMATIC CONTROL OF TRAINS

L. V. LEWIS

Engineer, Union Switch & Signal Company

AUTOMATIC train control may be defined as the control of the air brakes of a train by an automatic device operative only in case the engineman fails to control the speed of the train properly. For the accomplishment of automatic control three consecutive steps are required. The first involves means for determining the conditions of safety and occupancy of the track ahead of the train for a distance which is greater by a safe margin than the braking distance at maximum speed; the second, means for transmitting a sufficient indication of the track conditions from the roadway to the train; and the third, means for automatically determining when and how the train brakes shall be applied, acting in such a manner as to meet adequately the diverse conditions of train operation. The problem of automatic train control thus, in reality, contains three problems, and is not by any means limited, as has so often been wrongly assumed, to the single problem of obtaining a means for transmitting with safety and surety a stop indication from the roadway to the moving train.

THE PROBLEM

The problem of determining and indicating the track conditions is the only one of the three which may be said to have reached a point where opportunity for further radical development is lacking. The art of railway signaling to-day has reached a high state of development and is rapidly approaching standardization. Long experience has shown that fixed signals properly installed are adequate to protect fully a great variety of train movements, providing the signal indications are observed and correctly acted upon by the enginemen. This limitation to satisfactory efficiency in signals therefore defines the object of automatic train control, to prevent the disastrous results which may be incurred by failure to observe signal indications. It as well determines the field for automatic control as an adjunct to existing signaling systems. Since a device which can successfully apply the train brakes from the roadway might be employed instead to control a signal within the engine cab, the subject of cab signaling is usually considered together with that of automatic control, and cab signals are a feature of a great many schemes which have been patented from time to time. It, however, appears to be quite impracticable to give as complete information for governing train movements by the two or three possible indications within the cab as by the variety of indications which are possible with roadside signals. If the cab signal were used alone, its failure would be equal, in its effect upon the control of the particular engine carrying the defective signal, to the failure of a fixed signal system for the entire run; if a visual signal were used, its use would detract from the necessary attention to outside objects. Without a sacrifice in efficiency, the cab signal, therefore, cannot replace, nor be more than an adjunct to, a fixed signaling system.

HISTORICAL

The history of the automatic train stop as far as it relates to devices which have been brought into commercial use is brief. The first practicable device of which the writer is aware was patented by A. S. Vogt, an officer of the Pennsylvania Railroad, in 1880. This device consisted of a tell-tale arm mounted upon the signal mast and operated by the signal, and so arranged that, if the signal in the stop position were overrun, the arm would be in line to strike and fracture a glass tube projecting from the roof of the locomotive cab and in communication with the brake pipe of the train. The replacement of the glass tube necessarily consumed a time interval sufficient to bring the train to a stop from the maximum speed, and its loss provided the record of the event, desirable for purposes of discipline. Mr. Vogt's patent was bought by The Union Switch and Signal Company and a device for using it was advertised in the company's "Handbook" of 1889. A modification of this idea was installed by The Union Switch & Signal Company in 1901 upon the Boston Elevated Railway. In this installation the trip arm was mounted in the roadway, close to and outside the gauge line, and the glass tube was replaced by a valve. The same system, with minor improvements, was later installed in the New York Subway, the Market Street Elevated in Philadelphia, the London "Tube" and more recently, an improved system of the same type, in the Hudson & Manhattan and Pennsylvania Tunnel systems in New York and vicinity. Overhead stop systems of the same general character have also been installed upon two electric roads upon the Pacific Coast.

At the present time interest in the broad questions of automatic train control is exceedingly active, and several of the railroads are affording facilities for tests or have under consideration experimental devices of various types. The interest in this subject is evidenced by the eighteen hundred schemes which were submitted in response to a recent prize offer by the New Haven Railroad.

There have been numerous reasons advanced as to why simple train stops, operating so very successfully under special conditions, are not directly available for universal introduction into steam railroad service. Some of these reasons may be evident from the following discussion, in which it will be attempted to make clear the relation which the automatic stop bears to automatic block signaling.

SPEED SIGNALING

The Railway Signal Association and American Railway Engineering Association have recently agreed upon a standard signaling system which is being quite generally adopted by the railroads for new work, which is founded upon the basis of speed, and is known as "speed signaling." The only control which an engineman has over a train is over its speed; it is therefore considered logical that signal indications should instruct him explicitly as to the speed at which it is permissible for him to run in preference, for example, to the prevous practice of providing signals for indicating diverging routes which required interpretation into terms of permissive speed by the engineman before they could be acted upon. The principal signal indications are defined as follows:—

1—Proceed.
2—Proceed with caution.
3—Proceed at medium speed.
4—Proceed at low speed.
5—Stop.

The speed under the first indication is usually limited by rule to some predetermined maximum value; the second indication means proceed, prepared to stop at the next signal; the third is used at a cross-over, or at the entrance to a diverging route; the fourth is used at the entrance to a siding or to an occupied block. The fifth indication, when used at an interlocking plant, means that the signal is not to be passed until permission has been received; at an automatic signal it means that the signal may be passed with caution after a full stop has been made, with the expectation of finding the block occupied, an open switch, broken rail, etc. It is to be noted that, of these five indications, four contain instructions which provide for continued movement of the train, and the fifth provides for proceeding either at once or as soon as permission is received.

The function of the automatic stop is obviously to stop trains The general public impression is that this is also the purpose of a block signaling system but, as a matter of fact, this is not the case; the purpose of block signals is to enable trains to run; or, more specifically, to enable trains to run safely at speeds higher than would be possible without their use.

THE AUTOMATIC STOP

For the purpose of determining the effect of the introduction of the automatic stop, consider a "home" signal having the two indications "stop" and "proceed" (one of which is the same as that of the automatic stop) and a hypothetical block signaling system for a double track road, in which this type of signal only is used at the entrance to each block. Evidently the maximum speed permissible with such a system would be the speed at which a train could be brought to a stop within the distance between the point at which a signal first becomes visible and the signal. If a second train were just beyond the signal, it would likely be visible as soon or sooner than the stop signal and would serve as an equally good stop indication. Such a signal system would obviously be valueless for high speed running and in fact would never be installed unless for the purpose of meeting some special condition, such for example, as to secure a definite spacing between trains, which operate only at low speed. It is also obvious that no complete protection could be secured by installing automatic stops in connection with such a signal system. The feature lacking in this assumed signaling system, whose absence destroys the value of the system, is the distant signal, whose two indications are "proceed with caution" and "proceed." For high speed running a distant signal should be installed at least at maximum braking distance in the rear of each home signal, and generally would be installed a full block in the rear, at the same location as the preceding home signal. It is the distant signal which renders high-speed running safe, by giving the engineman advance information in time for him to apply brakes to reduce his speed so that a stop may be made before passing the home signal. The action taken by the engineman, it should be observed, is a variable which depends upon the speed of his train.

The automatic stop must evidently be located at the point at which the brakes are to be applied and not at the point at which the stop is to be made; that is, the stop should be located at the point which, in the usual home and distant signaling system, is occupied by the distant signal; this signal therefore becomes a home signal, so that it may give the same indication as the automatic stop, and the distant signal must be moved a block further back, or two blocks in the rear of the entrance of the block and the controlling circuits overlapped one block. This system is the one which so far has been generally installed where automatic stops have been used, and is known as the "overlap block system." It gives at all times one full clear block in the rear of the train.

The introduction of the simple automatic stop into existing signaling systems usually means a complete rearrangement of signals and also a reduction in track capacity. It is apparent that any lack of harmony between automatic stop systems and signaling systems must be overcome in order to make the automatic stop available for general introduction, and that this harmony should be attained, not by changing all existing signals to suit the stop, but by so controlling the stop system that it will fit in with accepted signaling practice.

Speed Control—The way has been made clear for the solution of this phase of the problem of automatic train control by the development of the idea of speed signaling. The development of this idea has shown that the purpose of every signal indication is to define the speed—either directly or otherwise; the obedience of the engineman—or the lack of it—is in consequence made manifest by the speed of the train. The automatic stop should therefore be governed by a speed control device, operating in connection with the block signals, which becomes effective whenever the permissive speed defined by the signal indication is exceeded. The requirements to be met by such a device are not by any means simple. Three conditions are the provision of maximum, medium and low speed limits controlled by corresponding signal indications. A fourth is provision of a control varying from a maximum to zero speed between a distant signal at caution and the next home signal at stop, which will become immediately ineffective if the home signal goes to the proceed position. The device should contain elements which are a part of the roadside equipment, in order to meet the varying requirements of control from point to point along the roadway. It is equally desirable that it contain elements which are a part of the engine equipment, if more than one class of traffic is to be provided for, since it is obvious that the same speed values are not applicable to both freight and fast passenger service. Maintenance and cost of installation dictate that the device be located upon the rolling stock in preference to the roadway. In the case of one of the roads which is completely block signaled the ratio between the number of signals and the number of locomotives is eight to one.

The problem of automatic train control is thus seen to be chiefly a problem of speed control. The development of speed limiting devices for the control of trains may follow one of two lines. The first, and the most obvious, is by direct speed measurement, as by means of a centrifuge or by measurement of induced electromotive force; the second is by averaging the speed over a given distance, by measurement of the time required to traverse a spaced interval upon the roadway..

The engineering difficulties in the way of complete train control by speedometer methods are serious and have not yet been wholly overcome. For the second method, a partial illustration is afforded in the automatic stop installations on the New York Subway and on the Hudson & Manhattan Railroad which, on account of their interesting character, may be worth a detailed description. These roads are unique in having particularly uniform track conditions and character of traffic, except for a few points of congestion as exemplified by the express stations in the subway. The application of speed control to these particular points has increased their train capacity to a point almost equal to the remainder of the lines operating under the overlap block system; the latter, therefore, ceases to be a detriment but on the other hand becomes a positive advantage on account of the enforced train spacing thereby secured. The speed control equipment used in these installations is contained in a number of intermediate signals located at short intervals between the distant and home signals approaching the express stations, each signal being, of course, provided with an automatic stop equipment. Ordinarily, the entire group of signals is in the "proceed" position. If a train is at the station platform, the group of signals, which extends the usual overlap block distance in the rear of the entrance to the block, are at "stop", a following train passing the distant signal will set a clockwork mechanism attached to the signal into operation, which after a predetermined time will close a circuit to clear the first stop and signal ahead of the train. If the speed of the train is slightly reduced, it will pass this first stop without interferance. As it passes the first stop and signal, it will set a clockwork into operation which controls the second signal; and so on, the allowable speed through each short section being so proportioned that the speed of the train must be gradually reduced to a very low value as it approaches the home signal. The final result is that an enforced control by automatic stops is obtained, which is exactly similar to that obtained with a careful motorman running under the usual home and distant block system and the delay inherent to the overlap block system is obviated.

Classification—Automatic stop and cab signaling systems may be classified according to the character of control employed as, intermittent or continuous control. They may in addition be classified according to the medium for effecting the control as, mechanical trip, electric contact, track circuit or inductive devices. The term "electric contact" refers to contact rails or similar devices; "track circuit" refers to systems which provide a circuit from the rails to the engine by insulating portions of the train equipment.

Intermittent and Continuous Control—Intermittent control may correspond to the sort of control that is given by the present fixed signaling systems; continuous control is frequently assumed to be preferable on the ground that the weak link in automatic block signaling is in the use of a fixed distant signal. For ideal results, the distant signal should remain in full view of enginemen after it has been passed and until a distinct view is had of the next home signal which it repeats or, in other words, the distant signal indication should be duplicated within the cab. The usual scheme for continuous control is to provide a continuous conductor, for energizing the cab apparatus, which extends throughout the length of the block in the rear of the home signal and whose energization repeats the indication of the home signal. The supposed advantages of such an arrangement are two:—

First, ability to give an earlier stop indication upon the withdrawal of the home signal indication after the distant has been passed at proceed.

Second, avoidance of delay in the block when the distant signal has been passed at caution and the home signal cleared immediately thereafter. The first advantage is of but slight value, as it fails to provide any definite overlap distance for stopping high speed trains. A simple means for preventing the withdrawal of the home signal after the distant has been passed is at present available in the well known "approach locking." The second advantage above mentioned is lost because of the fact that it is not safe under *all* circumstances to permit an engineman to be governed by the indication of the next signal in advance. An example is when a train has entered an occupied block under caution, according to rules, after having been stopped by an automatic signal at "stop." As soon as the train enters the block, the cab signal, if one is used, will indicate "proceed" provided this is the indication of the next fixed signal ahead, and would evidently give a false indication, conflicting with that of the fixed signal at "stop" which the train has just passed, whose indication as already explained should govern the movement of the train through the block. An automatic stop if controlled in the same way would evidently fail to prevent the train from running into a train ahead, in the same block. Caution is demanded through the block even if the home signal ahead is clear, and whether it is visible or not.

The unsafe feature in this situation has been avoided in one scheme by the use of a short intermittent conductor at the end of each block in addition to the main conductor. The circuits are arranged so that if the relay on the train is de-energized in any block, it cannot again receive energy until the train has moved clear to the end of the block in advance, and has reached a fixed signal at proceed. This remedy brings the scheme into the intermittent control class, with regard to the results obtained. The advantage of so-called "continuous control" is thus largely a fallacy.

The problem of bridging the gap between the roadway and the moving train, so often assumed to be the entire problem of train control, has naturally received a tremendous amount of study, and the end is not yet reached by any means. No scheme absolutely free from objection has yet been discovered nor is one likely to be. Electric contact cab signaling systems are in use to a limited extent in Europe, but experience with the collection of current at low voltage by a moving vehicle under American weather conditions is almost entirely lacking. Track circuit and inductive schemes, while attractive as presumably avoiding the problems of inertia, clearance, weather, and alignment, with which mechanical or electric contact devices are particularly concerned, have so far not attained a degree of development which would warrant their introduction into the equipment of modern railroads.

A great deal of energy has been misdirected in efforts to bring schemes, inherently unsafe, into conformance with the necessary requirement that "a failure of any essential part should cause an application of the train brakes" by loading them with protective devices or circuits of one sort or another, often overlooking the fact that the protective devices themselves may fail. It should be obvious that protective circuits which do not detect their own failures are unsafe and in consequence valueless. Granted, in a complicated electrical scheme, that every possible failure will procure an application of the brakes, will these failures occur frequently enough to be a prominent cause of train delays, or what sort of protection will the device give after the accidental brake application has been incurred? Questions of this sort, together with difficulties of maintenance, render the success of any inductive scheme open to doubt, and the general opinion seems to be that mechanical devices are to be preferred on the grounds of superior reliability, safety, and simplicity. The mechanical problems of clearance and alignment are simple in comparison with those encountered in electrical schemes, as they are of a nature readily understood and hence capable of solution by the forces regularly engaged in the maintenance of track and equipment.

Methods of Applying Brakes—The automatic stop systems in commercial use have generally been arranged to give a full emergency application of the brakes. An emergency application can be made in a very simple way—by venting the brake pipe to atmosphere through an orifice large enough to throw the triple valves to emergency position in spite of the efforts of the compressor. An emergency application may be a source of discomfort if made on a passenger train at low speeds and becomes a positive source of danger if made on a long freight train, in fact, the effect is exactly similar to that produced by the bursting of a brake hose, which has in certain instances been the cause of serious accidents. Any system of train control to be suitable for use in all classes of service must provide for service as well as emergency brake applications. A service application is made by exhausting the brake pipe at a rate less than that required to produce an emergency. This suggests the use of the same simple valve, but with a proportionally smaller orifice, but unfortunately this simple method will not answer, for if the orifice is adjusted, as is usual, with the engineer's valve in the running position, the application may be partially or entirely prevented by throwing the engineer's valve to the release position. The automatic stop should cut off the engineer's valve when making an automatic application, but only to prevent a manual release, and not a manual application at the same time, if it should be required. It is also of importance to limit the brake pipe reduction to the equalization pressure, unnecessary loss of air meaning both delay and loss of braking power.

The subject of automatic train control is one of interest to practically all departments of railroading. The maintenance of way, signaling and motive power departments are directly concerned with its operation and maintenance. It is of interest to the operating department in its effects upon train movements, and to the executive department as a question of railroad policy.

PNEUMATICALLY-OPERATED DRUM CONTROLLERS

A. J. HALL and L. G. RILEY

IN 1897 pioneer steps were taken in the development of multiple-unit control for electric trains. Up to that time the hand-operated drum type of controller had been used for all classes of equipment, and it was natural that the first multiple control apparatus should take the form of a remotely controlled drum type controller. Multiple-unit equipments of this type were first placed in operation on the Kings County Elevated Railways of Brooklyn, replacing steam service.

NOTCHING HEAD

One of these forms of equipment consisted of a drum controller, pneumatically operated and remotely controlled through a master controller. The operating mechanism included two separate cylinders with pistons producing a reciprocating action, for governing the "on" and "off" movement of the main or accelerating drum, and a third cylinder for operating the reversing drum. Valve magnets controlled the admission and release of air from the cylinders and energy for the control circuits was supplied from a storage battery. In order to get step-by-step progression of the main drum, the operating cylinder was arranged to drive the drum through a dog on the piston and a ratchet on the drum, one full stroke of the cylinder being required for each notch. In preparation for the next notch the piston was returned by spring pressure to its initial position, where the dog engaged the succeeding notch in the ratchet plate. A form of magnet valve, in which air was admitted to the cylinder when the magnet was deënergized, was connected to the release cylinder and served to return the drum to the "off" position whenever the control circuits were opened. A series relay adjusted for a predetermined current, limited the rate of acceleration and prevented careless operation of the trains. A large number of controllers of this type are in successful operation today.

THE PILOT MOTOR

Another form of equipment consisted of a controller drum operated by a pilot motor geared to the controller shaft and controlled by a master controller operated from the line. The features of this equipment were the brake on the pilot motor for stopping the drum on successive steps, and the means for reversing the motor and returning the drum to the "off" position. A series motor having two separate field windings was manipulated by the master controller circuits to drive the controller drum forward while the master controller was in an operating position, by passing current through the "on" winding. With the master controller in the "off" position, circuits were established which energized the other field of the pilot motor, this field being connected to reverse the direction of the motor, and the controller was thus returned to the "off" position. A spring brake on the pilot motor shaft was released by a limit switch in its down position, thus allowing the drum to progress automatically notch by notch. Modified forms of this equipment are now in service on a large elevated system.

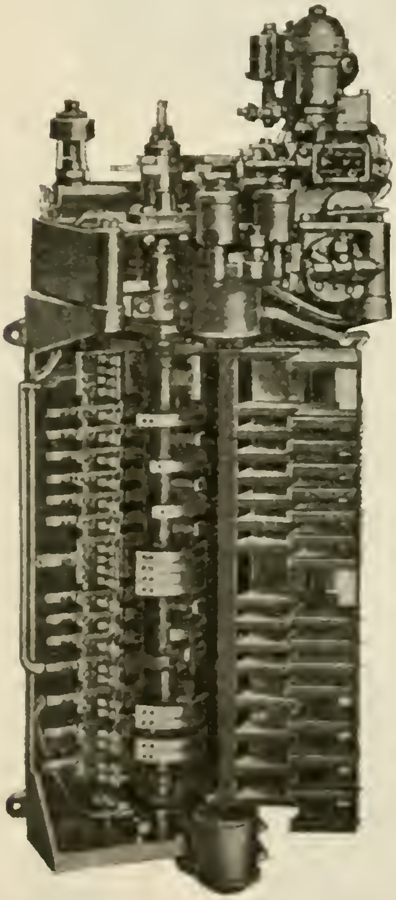


FIG. 1—NOTCHING HEAD TYPE OF PNEUMATICALLY OPERATED DRUM CONTROLLER

DEVELOPMENT OF THE UNIT SWITCH

While the detail construction of multiple control apparatus has advanced with the changing conditions and requirements, the fundamental principles of the modern elevated or subway equipment can be traced directly to the results of tests on the original power-operated drum control equipments.

The mechanical difficulties encountered in the drum controller operating mechanism of both types, together with the inherent limitations of a drum controller for opening heavy arcs and for sustaining overloads, retarded progress along the lines originally planned and led to the development of a variety of remotely controlled power-operated switches, called plunkers, contactors and pneumatic switches. The aim of these designs was to concentrate heavy pressure, positive action and effective magnetic blowout, on separate pairs of contacts, which could be inserted in the motor circuits at the proper points and closed in the proper sequence to produce the desired speed combinations.

This development has lead through various forms of remotely controlled unit switches and contactors down to the standard multiple-unit control apparatus of today. The first electro-pneumatically operated switch was in the form of the Turret Switch group, where

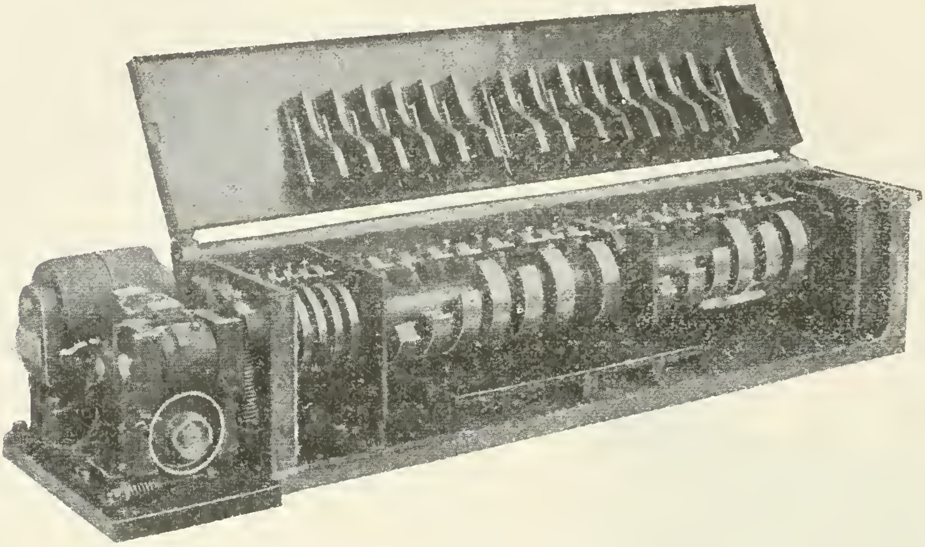


FIG. 2—DRUM CONTROLLER OPERATED BY A PILOT MOTOR

thirteen air cylinders were cast "en bloc" with air passages cored in the circular frame castings. Then followed the rectangular unit switch group, which has undergone a series of modifications until the modern unit switch is standardized for a wide range of capacities in car and locomotive equipments.

The advent of the hand-operated unit-switch control operated by line power extended the application of power-operated control

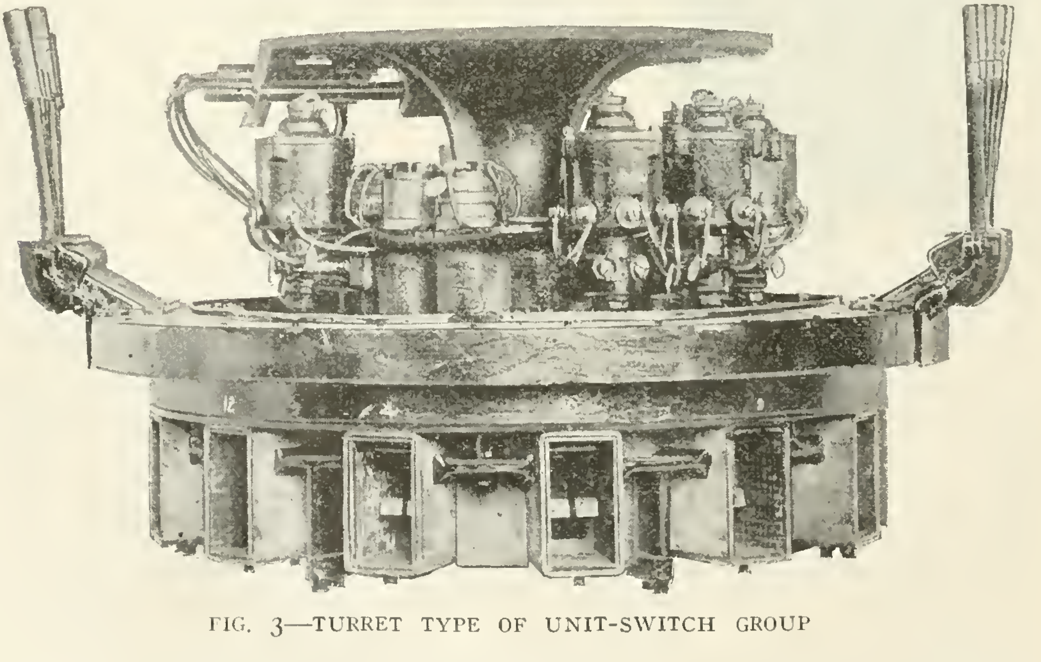


FIG. 3—TURRET TYPE OF UNIT-SWITCH GROUP

apparatus, with its well-known advantages, to city and interurban service for both single car and train operation. However, the active campaign for extremely light weight cars with maximum seating capacity necessitated the development of a more compact form of control equipment than could be secured with unit switches alone. Such an equipment is now available in the "P K" type of control, so called from the fact that it is a pneumatically operated "K" or drum type controller.

THE "P K" TYPE CONTROLLER

While the apparatus here described applies particularly to equipments in use on the stepless cars of the New York Railways, there is a wide range for the application of the principles involved.

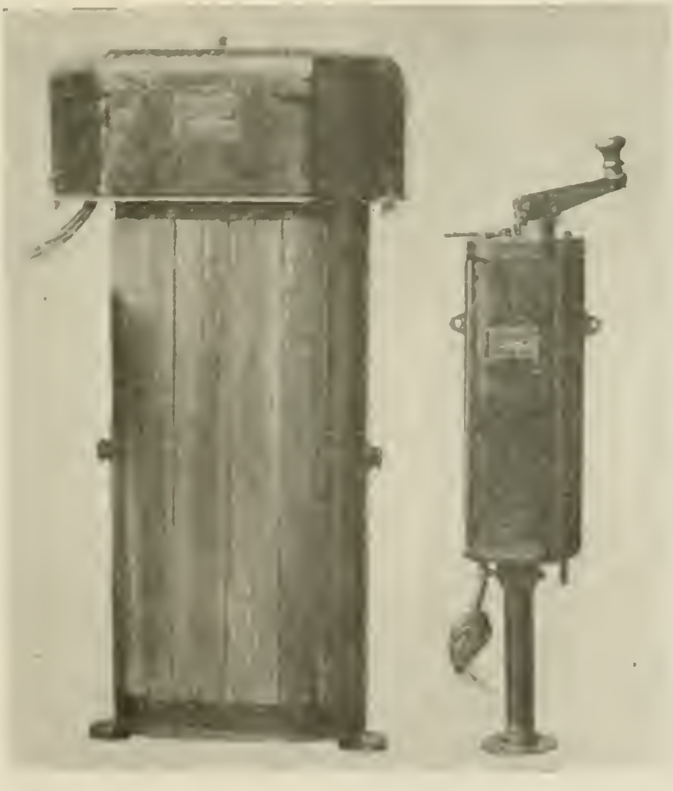
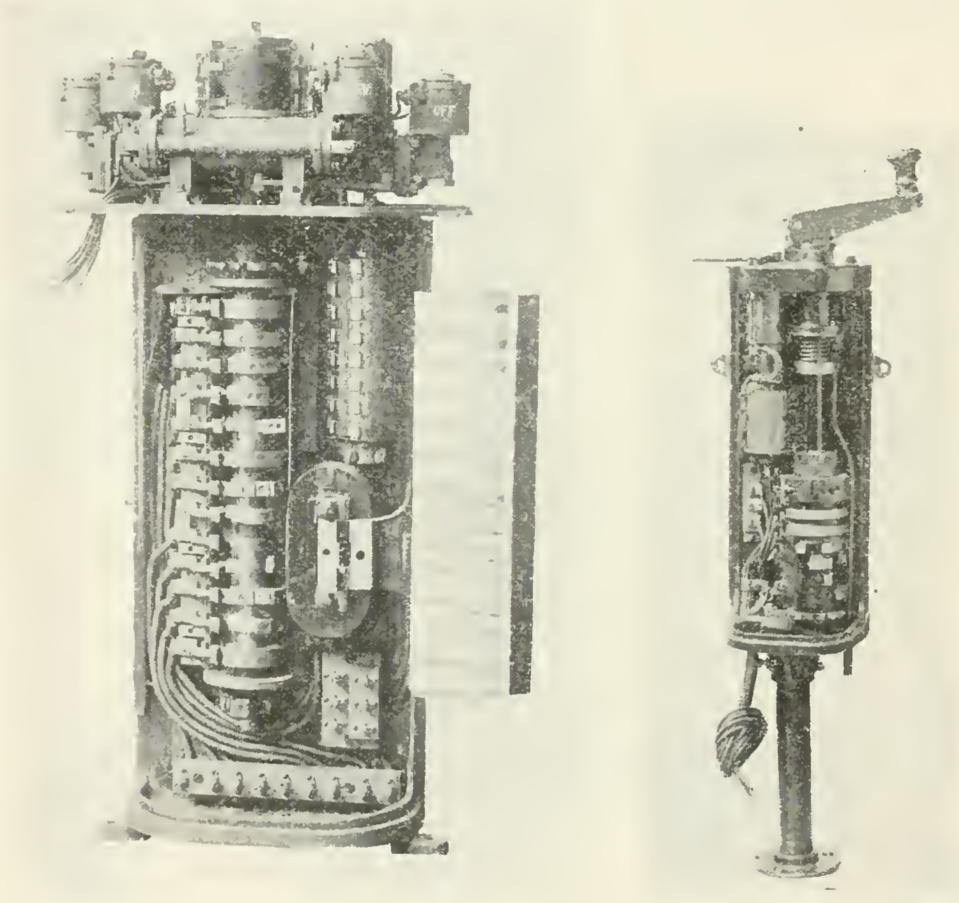


FIG. 4—P K COMMUTATING SWITCH AND MASTER CONTROLLER

The drum controller is at present the most compact as well as the most flexible means of producing a variety of combinations of electrical circuits, and with the means at hand for simple and absolute remote control of the drum movement, together with absolute protection against arcing, a long sought ideal has been realized. The difficulties encountered in the original power-operated drums have been entirely eliminated.

Mechanical Arrangement—As indicated by Fig. 5, the "P K" controller is a drum type controller with an operating head attached. The mechanism for operating both the main and reverse drums, is mounted on a base casting which takes the place of the controller top. It consists of two pairs of cylinders, one for operating the main drum and the other for operating the reverse drum. A cross-section of the operating mechanism for controlling the movement of the main drum is shown in Fig. 7. A small pinion, Fig. 8, on the main drum shaft meshes with a rack cut in a piston rod, connecting two pistons which slide in two corresponding cylinders. These pistons are controlled by two different types of valve magnets, one called the "on" valve magnet, and the other the "off" valve magnet.



FIGS. 5 AND 6—P K COMMUTATING SWITCH AND MASTER CONTROLLER, WITH COVERS REMOVED

The valve parts are so arranged that the "on" valve magnet, when energized, *admits* compressed air to the "on" cylinder, and the "off" valve magnet, when energized, *releases* air from the "off" cylinder.

The forward movement of the drum is obtained by energizing both magnets at the same instant, which will admit air into the "on" cylinder, and release air from the "off" cylinder, causing the main drum to move in a clockwise direction. The return movement is obtained by deënergizng both magnets, which will admit air into the "off" cylinder and release the air from the "on" cylinder. To stop the drums during the forward movement, the control circuit of the "off" valve magnet is broken, which will admit air into the "off" cylinder, thus instantly creating an equalization of pressure in both cylinders. In order to obtain the correct stops on the notches, as provided on the main controller drum, the control circuit of the "off" valve magnet, is broken on an auxiliary interlocking drum, which is connected to the same shaft, the development of which corresponds to that of the main drum, each notch being controlled by a separate control wire which is energized from the master controller.

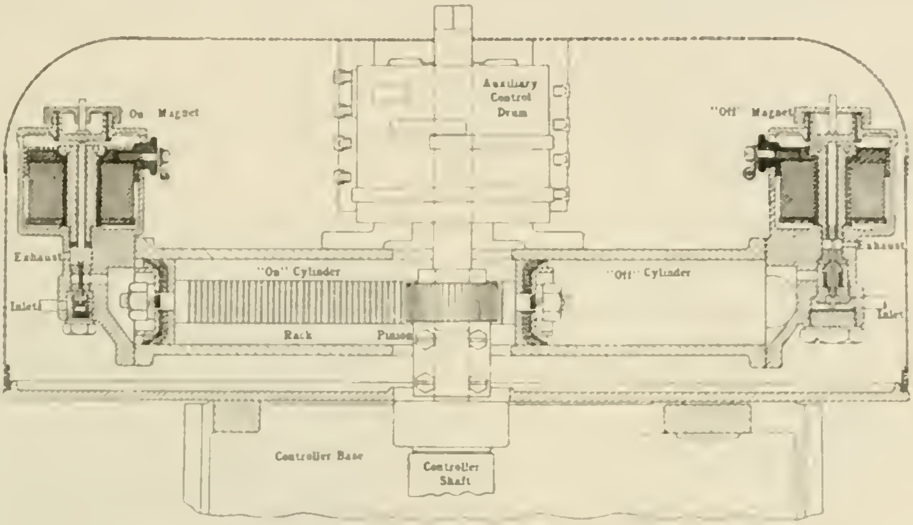


FIG. 7—CROSS-SECTION OF OPERATING MECHANISM

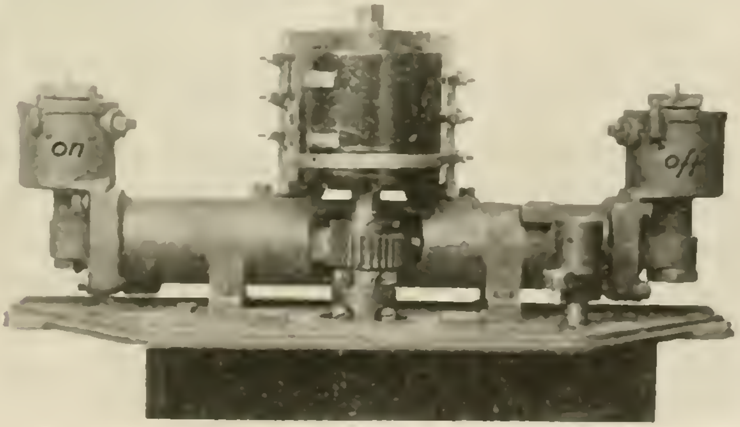


FIG. 8—OPERATING HEAD WITH REVERSING MECHANISM REMOVED
Showing rack and pinion drive.

The reverse drum is operated in the same way as a standard electro-pneumatic reverser. The two cylinders are in line, with pistons connected by a common rod, so that when compressed air is admitted to one of the cylinders, the reverse drum moves to the opposite position. A link connects from the piston rod to a lever on the reverse drum shaft.

Main Circuits—The main circuit connections, shown in Fig. 9, which illustrates a two-motor field-control equipment, are arranged in such a way as to relieve the main drum of all unnecessary work. This is accomplished by a line switch, shown in Fig. 10, which is connected in the circuit ahead of the controller, to do all the heavy making and breaking of the circuit. The controller drum is so arranged that its "off" position corresponds to the first notch on the master controller.

The line switch is electro-pneumatically operated, and provided with a strong magnetic blow-out, its construction being similar to that used on standard unit-switch control equipments. An overload trip, Fig. 11, is connected in the circuit ahead of the line switch so as to protect the equipment against overloads or short circuits.

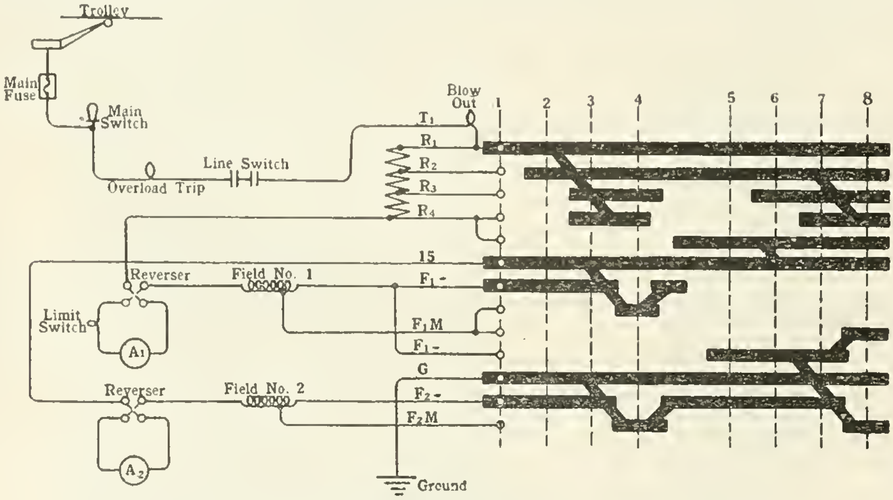


FIG. 9—SCHEMATIC DIAGRAM OF MAIN CIRCUITS

The main drum is arranged with a total of eight notches, four in series and four in multiple. Notches two and three in the series position, and six and seven in the multiple position, cut out resistance steps; notches four in the series and eight in the multiple position, change the motor fields from full field to normal field connection.

Control Circuits—The master controller, Fig. 6, has two handles, a reverse handle and main handle, the reverse handle only being removable. The main handle is arranged with an emergency interlocking feature, in such a way that should the motorman release the handle while it is on any notch except the "off" position, power will be immediately cut off and the brakes applied to the car.

The emergency brake application may be prevented in the "off" position by moving the reverse handle to neutral. The mechanical interlock for accomplishing this result is located at the top of the controller. The reverse drum fingers slide on the reverse drum when the main handle is released, opening the forward and reverse wire circuit, thus dropping out the line switch. At the same time the upward movement of the main handle unseats a small pin valve which applies the brakes.

A sliding contact, Fig. 12, is located above the main drum of the master controller. This is made up of two pieces of moulded material which are clamped around the shaft by means of spring clamps. A stop on the main base allows the sliding contact to turn through an angular distance corresponding to one notch of the main drum. During the balance of the movement of the main drum, the sliding contact is stationary. With this arrangement, if the master controller is moved towards the "on" position, the control circuit for the line switch is established, while any backward movement of the controller handle opens this control circuit, thus dropping out the line switch. In this way, the arcing on the main controller drum, when backing off the resistance notches, and in going from multiple back to series position, is entirely eliminated.

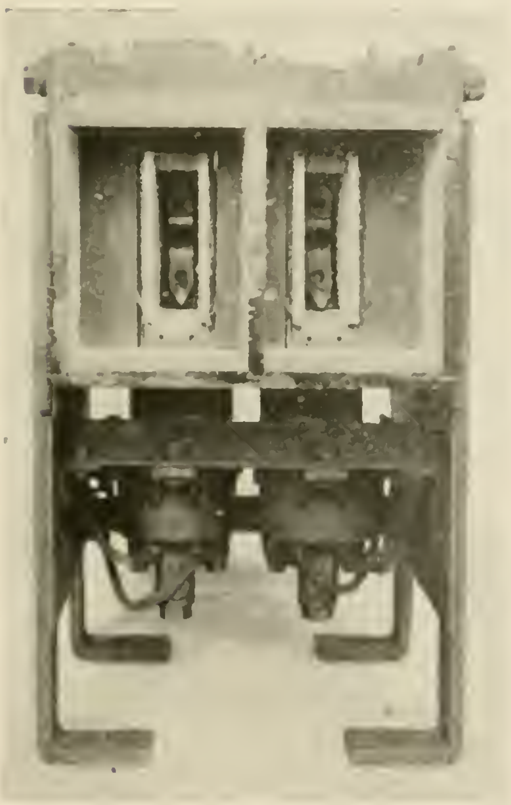


FIG. 10—PNEUMATICALLY - OPERATED LINE SWITCH WITH MAGNETIC BLOW-OUT

The development on the main drum of the master controller provides positions corresponding to the notches of the controller drum, arranged so as to make it possible to pause on any one of the eight notches. Automatic acceleration is obtained by connecting the current limit relay in the control circuit of the "off" valve magnet, permitting the master controller handle to be thrown directly to the full multiple position, and any predetermined rate of acceleration maintained according to the setting of the limit switch, as indicated by the schematic diagram, Fig. 12.

On the first notch of the master controller, wire *1* is energized from *6*, which is the positive side of the control circuit. Wires *F* and *R* are energized from the wire *0*, which is the negative side of the control circuit. Wire *1* is interlocked through the main controller drum in the first position, to wire *13*, to the line switch valve magnets, to the return circuit through wire *10*, which is interlocked through the reverse drum to wire *F* or *R*, and then through the reverse drums and sliding contacts on the master controller to the negative side of the control circuit. As soon as the line switch closes, wire *13* is connected to wire *1*, which establishes a holding circuit. Current through wire *1* also energizes the "on" valve magnet which is connected directly across wires *1* and *0*, so that the main drum will not come back to the first position until the master controller is thrown to the "off" position.

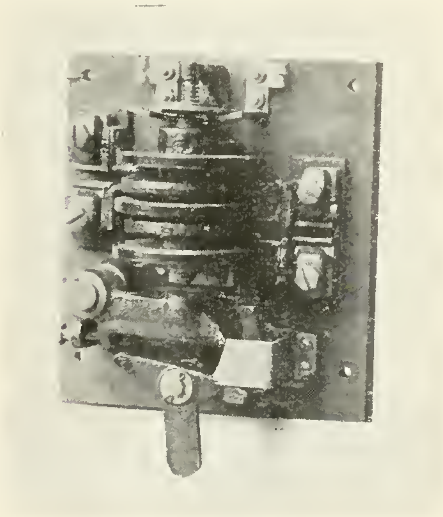


FIG. 11—OVERLOAD TRIP

On the second notch of the master controller wire *2* is energized, and the current goes directly to the auxiliary interlocking drum on the main controller, which energizes the "off" valve magnet through wire *14* and the limit switch to the "off" valve magnet coil, and returning to the negative side of the line through wire *10*. This releases the air from the "off" cylinder, and the "on" valve magnet being already energized, the main controller drum moves toward the second position. Just before it reaches the second position, the current in wire *2* is interrupted on the auxiliary control drum, thus deënergizing the "off" valve magnet, which instantly establishes equal pressure in both cylinders, stopping the main drum on the second position. The control wires *3* and *4* operate in a similar manner, and control the resistance and field notches in series as well as in multiple. The *P* wire when energized operates the main controller drum from the series to the multiple position.

The power for operating the control circuits can be obtained from a storage battery or direct from the trolley through a control resistance. In either case an extremely small amount of energy is required for control, since only four valve magnet coils are necessary to operate the entire equipment.

Advantageous Features—Primarily, the P K type of control equipment is designed for the absolute minimum of weight and space. In order to meet the conditions on extremely low floor cars, it is possible to mount the entire equipment in the motorman's cab. When so mounted the apparatus is extremely accessible for quick inspection and maintenance, and these are important items where cars are in use for nearly the entire twenty-four hours of the day.

As indicated by Fig. 12, the almost complete absence of interlocks and complicated circuits points to an extremely simple control equipment, such as the average inspector can easily comprehend. Mechanically, the device is as simple as it is electrically.

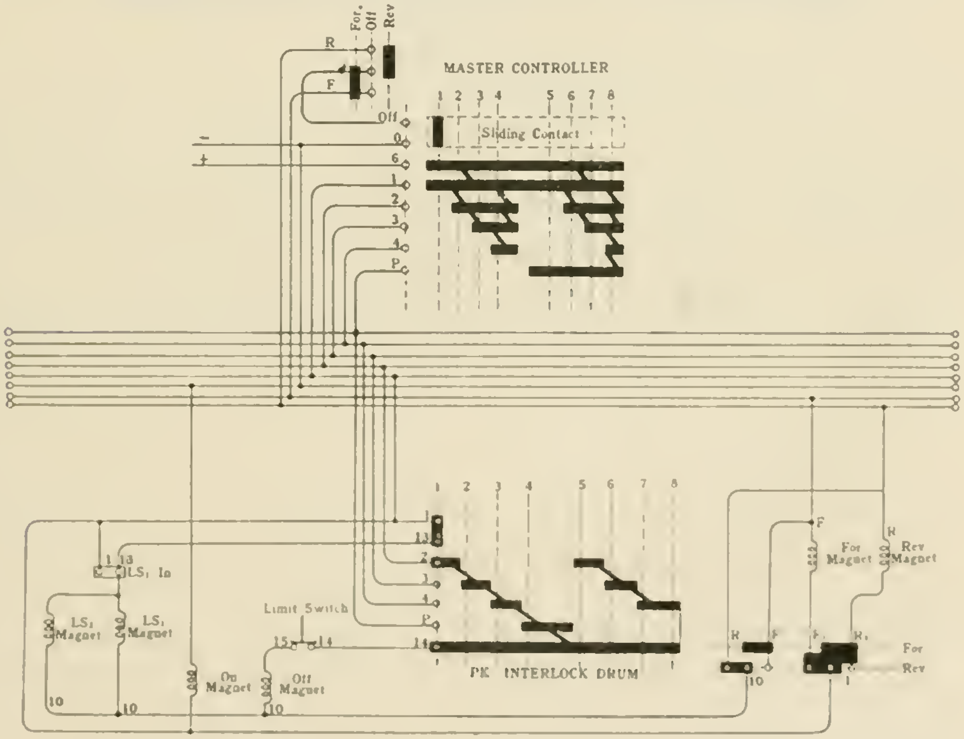


FIG. 12—SCHEMATIC DIAGRAM OF CONTROL CIRCUITS

Never before has a car equipment been built, involving as its inherent fundamental features, the possibility of accelerating either manually, notch by notch, or automatically, on either a time element or a constant current basis. The advantages of these features, especially on city cars in dense traffic, are readily seen. When possible, the car must be accelerated at the maximum rate permitted by adhesion in order to maintain schedules. The limit setting fixes this rate and prevents loss of time from the slipping of wheels or opening of the overload trip. When held back by traffic a large number of operating notches are available to suit any necessary speed.

In the railway field alone the application of this system of control is unlimited. Wherever power circuits can be manipulated more easily on a drum than with individual switches, this new arrangement solves the problem of remote control and proper regulation for the drum. Any intermittent motion in two directions, either rotating or rectilinear, is readily controlled by the application of this scheme. One good example of such an application is the regulation of the height of electrolyte in a liquid rheostat by raising and lowering the overflow pipe. The original application to small cars can be extended to larger equipments as conditions demand.

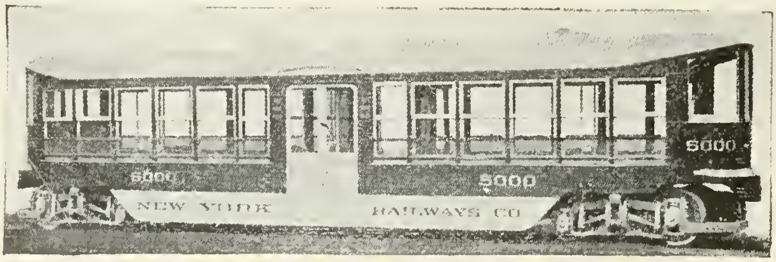


FIG. 13—STEPLESS CAR OF THE NEW YORK RAILWAYS CO.
Equipped with P K Control.

ELECTRIFICATION OF TRUNK LINES IN EUROPE

R. E. HELLMUND

The author returned recently from an inspection trip of the more important European trunk line electrifications. A brief resume of the impressions received and the information gathered is given in the following pages.—(Ed.)

IT IS intended to give in this article merely a general idea of the conditions of the electrifications in Europe, rather than to deal with the details of design. A number of factors are mentioned which are not of a technical character, but which are of importance in that they have had an important influence upon present conditions. The various countries considered are dealt with separately

GERMANY

General Situation—The German trunk line systems are practically all owned and operated by the larger states of the Union, as Prussia, Bavaria, Wuerttemberg and Baden. As Prussia has by far the largest railway system, it has taken the lead in electrification work. The following statements regarding the electrification in Prussia apply, therefore, in general to other German electrifications.

Electrifications in Prussia are at the present time in a rather unsettled condition and the results are, in the writer's opinion, not very satisfactory. The reason for this seems to be a rather too liberal policy of the government in allowing the trying out of a multitude of frills, combined with a rather one-sided attitude with regard to a number of essential features.

System of Electrification—The system of electrification practically settled upon is single-phase, about 15 cycles, 10 000 or 15 000 volts. This system was recommended some time ago in elaborate printed reports (Denkschriften) submitted to the Prussian government. The voltage of the overhead construction was not definitely settled in the beginning, but it was decided to operate first with 10 000 volts and in case this should give good results increase to 15 000 volts. This change is now being made at the Dessau-Bitterfeld road, since the overhead construction has given satisfaction with 10 000 volts.

While apparently the single-phase system will be the standard for German trunk line electrifications, there seems to be some doubt regarding the proper system for the Berlin Elevated (Berliner Stadtbahn). The electrification of this road has been carefully considered for many years and single-phase, 15 cycles has been recommended in view of the inter-connection of this road with the trunk lines entering Berlin. The Stadtbahn is a money losing proposition and the government found it necessary to appropriate 50 000 000 marks from which little or no return is to be expected. Under these conditions it was exceedingly difficult to get the bill through the Prussian House of Representatives, especially since the interests of the steam locomotive manufacturers are said to have exerted a strong influence against the electrification. In fact it was possible to pass the bill appropriating the first 25 000 000 marks only under the condition that the electrification of the Stadtbahn was considered only and that no electrification of the trunk lines running into Berlin would be considered in the near future. Under these conditions it is possible that a direct-current system may be decided upon. This however, would not affect the decision in favor of the single-phase system for trunk lines.

The above situation has been described somewhat in detail because the decisions made abroad are liable to have a certain influence in this country, and it is well to know under what conditions certain conclusions were reached.

Mechanical Design of Locomotives—The mechanical design of the locomotives at Dessau-Bitterfeld cannot, in general, be considered very successful. Several reasons seem to be responsible for this. First, the government practically dictated the policy of using one or two very large motors per locomotive and side rod drive, and eliminated schemes for applying gears altogether, thereby limiting the possibilities to a design which brings with it a number of inherent difficulties. Second, the mechanical design of the locomotives is made by the steam locomotive manufacturers, and from what could be learned they are not over anxious to make the electric locomotives a success.

So far three typical designs have been tried out on the Dessau-Bitterfeld road:—

1—A passenger type of locomotive with vertical side rods. Most of these locomotives have only one large motor. Only one locomotive, which was originally built by the Allgemeine Electricitats Gesellschaft for the Loetschberg electrification and was there rejected on account of not meeting requirements and subsequently bought by the Prussian government, has two motors and practically vertical side rods. All of these locomotives with one big motor, about five or six altogether, have sooner or later given trouble, due to the breaking of the cranks and crank pins. The mechanical parts have since been strengthened considerably, but have not been in service long enough to show that they are now sufficient to do the work.

2—The freight type of locomotive with four drivers, and a jack shaft, driven by one big motor by means of side rods inclined about 45 degrees. These locomotives have so far given best satisfaction in service, although they are subject to rather pronounced vibrations. There is little doubt, however, that some type of geared locomotive would have been a better solution for this service.

3—Quite recently a number of locomotives of a heavier type have been tried. These locomotives have two large motors driving a common jack shaft by a side rod inclined about 45 degrees. This design seems to be altogether a failure. One locomotive was tried on experimental runs and began to vibrate very severely at a speed of about 40 miles per hour. Subsequently, there was a big noise followed by smooth running. After the locomotive had been brought to rest, it was found that the crank pin of the jack shaft was missing. A second locomotive of the same type behaved quite similarly with the exception that the crank pin of the jack shaft and both of the inclined side rods were broken.

While two of the above designs have given trouble on account of the mechanical difficulties, it seems that the various bearings do not give any serious difficulty in operation, which is of interest, since American railroad engineers have been rather afraid of trouble along this line. It should be remembered, however, that the average German engine driver is more to be relied upon to take care of lubrication properly than is the case in this country.

On account of the doubtful results obtained with side rods and large motors, there is quite a tendency now towards gear arrangements. The progress is rather slow, however, because it is hard to overcome certain prejudices. The government has, however, now agreed to gears for slow-speed freight work and has permitted the Bergmann Company to build one experimental geared locomotive for high-speed work.

With regard to the design of motor cars, especially for the Berliner Stadtbahn, the government officials, as well as the engineers of the manufacturing concerns, are very much interested in the flexible drive and the flexible gears which are in successful use in this country, and indications are that one of the two arrangements will soon be tried out in Germany.

In connection with the Stadtbahn electrification, a cross between locomotive and motor cars is being considered. Some time ago a report was printed recommending locomotives for the Stadtbahn, principally in an endeavor to utilize the present rolling stock. Now there seems to be a feeling that motor car operation would be much better adapted for the service. Since it is desirable, however, to make use of the existing rolling stock, it is now intended to build so-called pulling trucks (Zuggestelle). These are simply trucks with two pairs of drivers and two motors and the necessary control apparatus, but without a cab. It is intended to put pantagraphs on the passenger cars with the instruments and the master controller in a compartment at the end of the first passenger car. It is apparently intended to use such trucks until the present rolling stock is used up, and then gradually work over to motor cars.

Motors—All of the motors on the German locomotives seem to be rather successful in operation. While insulation breakdowns and some other troubles have occurred, it seems that these defects were not of a serious nature and in general the motors are adequate to do the work for which they are designed, both with regard to commutation and heating. The following principal motor types have been tried:—

1—Doubly-fed series motor with or without weakened field at starting.

2—Doubly-fed series motor of the Bergmann type with arrangement for shifting the brushes for the purpose of speed regulation.

3—Winter-Eichberg motor.

It is now practically certain that all of the above types, except the doubly-fed series motor, will be abandoned in the future for railway work. The Winter-Eichberg motor is, in most cases, not fitted for railway work, as it is inherently adapted for relatively low speeds only, which in turn means that heavy motors have to be used. The Bergmann motor, while operating satisfactorily, is not adapted for multiple-unit control and requires, moreover, complicated mechanical arrangement for the brush shifting.

All of the motors are built without resistance leads with the exception of the Bergmann motor, which has a small resistance inserted between the commutator and winding. The results obtained without resistance leads are in all cases satisfactory. The Allgemeine Electricitats Gesellshaft, which has, in the old locomotives, a special controller for regulating the commutation, find that even this refinement is not needed. The problem of omitting the resistance leads is, of course, much easier in Germany on account of the low frequency and the smaller starting torques required, than is the case in this country.

Auxiliary Apparatus and Control—All of the transformers built so far for the German railways are of the oil immersed type Some of those inspected by the writer were of the core type and the mechanical construction did not seem to take the requirements of railway service properly into account. Some trouble, for instance, has been experienced due to the breakage of supporting porcelain insulators on the transformers. Altogether it appears that the mantle type of transformers as used in American single-phase locomotives and cars is much better adapted for traction purposes. The use of oil transformers is objectionable on account of the additional weight and, at the time of the writer's visit, the use of air blast transformers, as in American locomotives, was seriously being considered by government officials and engineers. At the same time, experiments for the purpose of increasing the capacity of the oil transformers were about to be carried out. In one of the locomotives, oil circulating tubes, placed at the front of the locomotive outside of the cab and connecting into the bottom and top part of the transformer tank, were being tried out. Although no reliable tests were at hand, it seemed that these tubes made a difference of about 10 degrees in the temperature rise, and the engineers were hopeful that the improvement would be sufficient to allow them to rewind the transformers from 10 000 to 15 000 volts, without reducing the capacity. This is desirable, as the government now wishes to try out an overhead voltage of 15 000 volts.

With regard to the control of the German locomotives, three essentially different methods have been tried.

1—Control by electrically-operated unit switches.

2—Control by induction regulators worked in connection with a small number of unit switches.

3—Control by brush shifting and a small number of switches.

The two latter methods are not to be used any more in new designs and the contemplated standard is the one mentioned first, which is nearest to American standard practice. The reason for discarding the induction regulator feature does not seem to be so much its unfavorable influence upon the power-factor, as the difficulty experienced with the regulator and the driving mechanism and motors. The vibrations of the regulator armatures with the frequency of 15 cycles seems to make it very difficult to keep them in working order. Another point against the induction regulators is the heavy weight, which is far in excess of a number of switches which may be used to do the work of the regulator. During the writer's visit, one of the locomotives with induction regulators worked fairly well, but it was also learned that in case of some other locomotives for which induction regulators had been contemplated it was altogether impossible to get the locomotives in working order, and the locomotives were changed over to unit switch control. The use of the induction regulator was one of the fads of the government officials, but it seems that they are now convinced that it is not a very satisfactory method. The control by means of shifting the motor brushes will probably also be abandoned, although it will be used on some locomotive by the Bergmann Company.

Recuperation of Energy—Up to the present, little consideration has been given to the recuperation of energy, or even electric braking. The experimental lines now operated do not have sufficient grades to justify any recuperating scheme.

Miscellaneous—With the exception of the troubles experienced on the induction regulators on account of vibrations, it seems that no serious difficulties have been experienced in consequence of vibrations. While the writer noticed quite an amount of vibration in some of the locomotives, it did not appear to be serious. It was stated, however, by one of the government officials that the freight locomotive type, which was not in operation at that time, showed more tendency to vibrate than any of the other locomotives. Altogether none of the German engineers seemed to be afraid of any serious trouble caused by vibration.

SWITZERLAND

General Situation—The results obtained in Switzerland in the electrification of trunk lines are at the present time rather encouraging. Although in the experimental stages a large number of the manufacturers experienced rather discouraging results, similar to those in Germany, others succeeded in developing some very successful locomotives which have since been adopted as standard. The principal electrifications in Switzerland are the three-phase electrification of the Simplon Tunnel, which has been in successful operation for from six to eight years, and the single-phase electrification of the Loetschberg Tunnel, which was about to be opened during the writer's visit. A motor car train as used on this road and the overhead construction is shown in Fig. 1, and one of the single-phase locomotives is shown in Fig. 2.

System of Electrification—The standard system recommended by a commission of Swiss engineers is single-phase, about 15 cycles, 15 000 volts. The decision for this system was made after careful consideration of the three-phase system, single-phase system and the direct-current system at 2 500 and 3 000 volts. The three-phase system of the Simplon Tunnel, while giving complete satisfaction is generally not considered to be as good a solution of the electrification at large. The high voltage direct-current system is not being considered seriously at present, but the engineers are rather interested in the developments made in this country along this line.

Mechanical Design of Locomotives—The best operating locomotive is the one designed by the Oerlikon Company with two large motors geared to a jack shaft by helical Citron gears and a side rod which was arranged at a comparatively small angle against the horizontal. The only disadvantage of this locomotive was that the motors were located near the ends of the locomotive which, with higher speeds, gave a tendency on curves toward straightening out the rails. The adopted standard of the Loetschberg electrification is, therefore, a locomotive which, while having many of the principal features in common with the experimental Oerlikon locomotive, is using a Scotch yoke drive with five drivers. The new locomotives of this type have a very substantial appearance, and have so far shown no serious defects. As they have not been in operation very long, any final conclusions cannot be made at the present time.

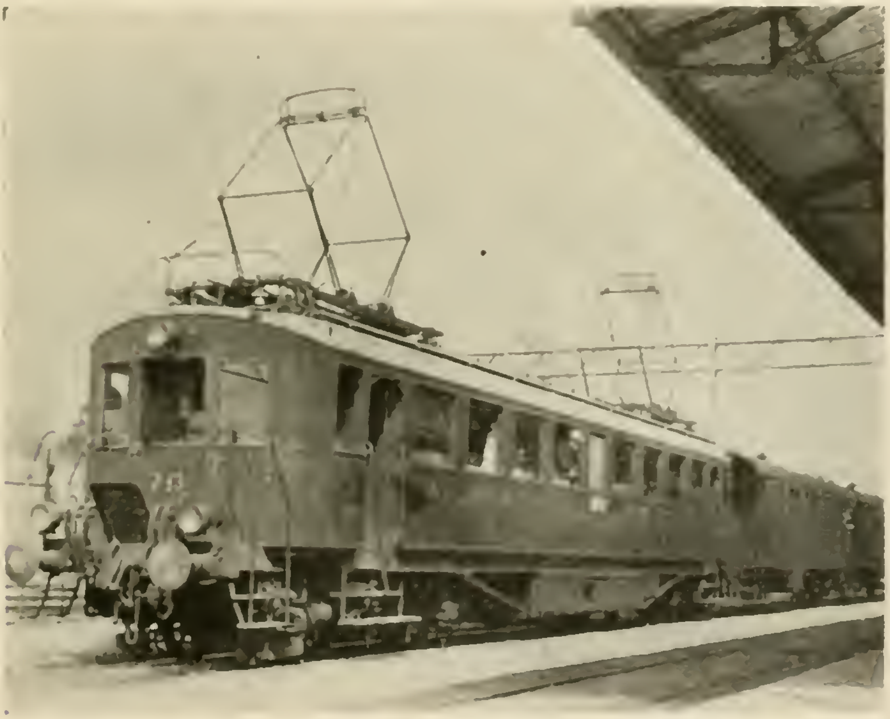


FIG. 1—MOTOR CAR TRAIN OF THE LOETSCHBERG TUNNEL ELECTRIFICATION

Two different mechanical constructions have been used for the locomotives of the Simplon Tunnel, one of them using three drivers and Scotch yoke, the other one using four drivers and a peculiar construction of frame drive and side rods.* Of these two constructions, the one with the Scotch yoke has given excellent results for a period of seven years, while the other locomotive does not seem to be quite as satisfactory in operation from a mechanical point of view. With regard to the Scotch yoke engine, it was stated by the master mechanic that they never experienced any trouble with the various bearings and that overhauling is not found necessary oftener than about once a year. The principal wear is in the window of the Scotch yoke, but this does not require much attention.

Motors—As in Germany a great variety of different motor types were used on the Loetschberg road during the experimental stage. Here also it was found that the motor types with brush shifting arrangements as well as the Winter-Eichberg motor and other repulsion motors are not very well adopted for traction work. The adopted standard single-phase motor is the Oerlikon motor, which is a series motor with interpoles and without resistance leads in the armature; the interpoles are connected in series with the other parts of the motor and a resistance is connected in parallel to the interpoles. With regard to commutation, this motor gives excellent results; it has the disadvantage of having certain losses in the shunt resistance. These losses are almost negligible in case of

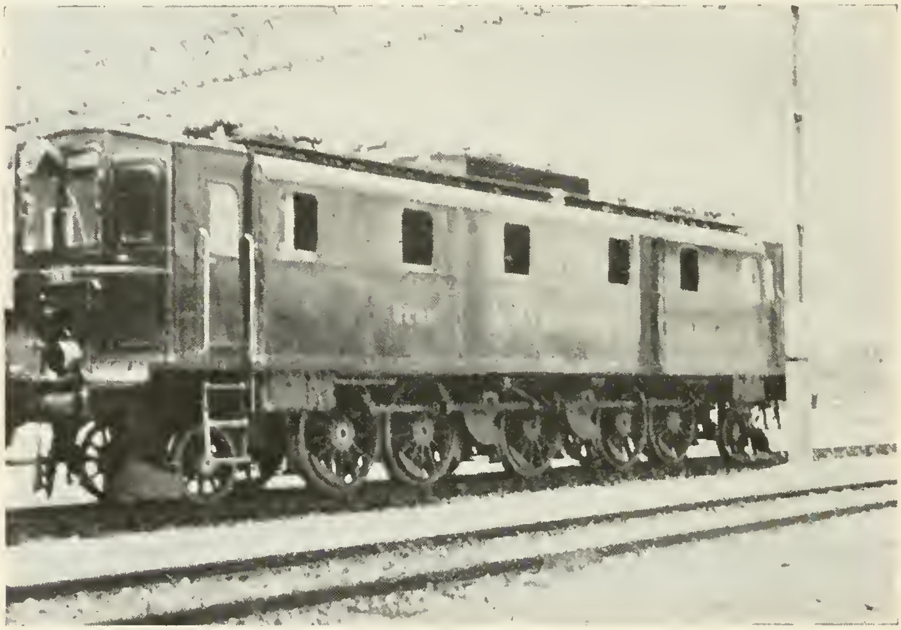


FIG. 2—SINGLE-PHASE LOCOMOTIVE USED ON THE LOETSCHBERG ELECTRIFICATION

the Loetschberg motors, because they run at an exceedingly high peripheral speed and with a frequency of 15 cycles. Unfortunately, these conditions are entirely changed in motors which are operated on 25 cycles and with the peripheral speeds customary in this country. Under this last named condition the shunt losses become almost prohibitive and we are therefore not in a position to adopt this otherwise exceedingly desirable type of motor.

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*See article by the author in the JOURNAL for June, 1910, p. 486.

The three-phase motors of the Simplon Tunnel locomotives have proven very satisfactory in service. During the writer's visit two of the motors were in for repair and the master mechanic stated that these were the first breakdowns in several years. Of particular interest are the squirrel cage motors of two of the later locomotives. This type of induction motor is generally not considered well adapted for traction work because all of the accelerating losses have to be dissipated in the motor itself, which is liable to lead to overheating and roasting of the winding. It seems, however, that these motors have stood up very well, since neither the primary winding nor the high resistance parts of the squirrel cage motor have required any repairs in several years.

Auxiliary Apparatus and Control—The control of the Loetschberg motor is of particular interest since the drum type of controller has been applied and is apparently giving good results. The regulation of this drum type of controller is affected by a mechanism very similar to the one used in connection with the Tirril regulator, separate contacts being provided for breaking the current. A similar type of drum controller operated by hand has been in successful use for about six years on some of the three-phase locomotives of the Simplon Tunnel. The only criticism offered by the master mechanic regarding this controller is that the oil surrounding the current breaker contact has to be renewed frequently. This is to be expected, as only one contact is being used for making all the breaks, of which 60 are required for each complete acceleration.

While these drum type controllers are apparently giving good results, it is not believed that they offer any advantage over the American type of unit switches. The Loetschberg controller is quite large and heavy and must be quite expensive.

Recuperation of Energy—Recuperation of power or electrical braking has not been attempted with any of the single-phase motors in Switzerland. In the three-phase locomotives a certain amount of recuperation is experienced. Due to the limited number of trains and the small grades of the Simplon Tunnel, this feature is of no very great importance. In the beginning most of the recuperated

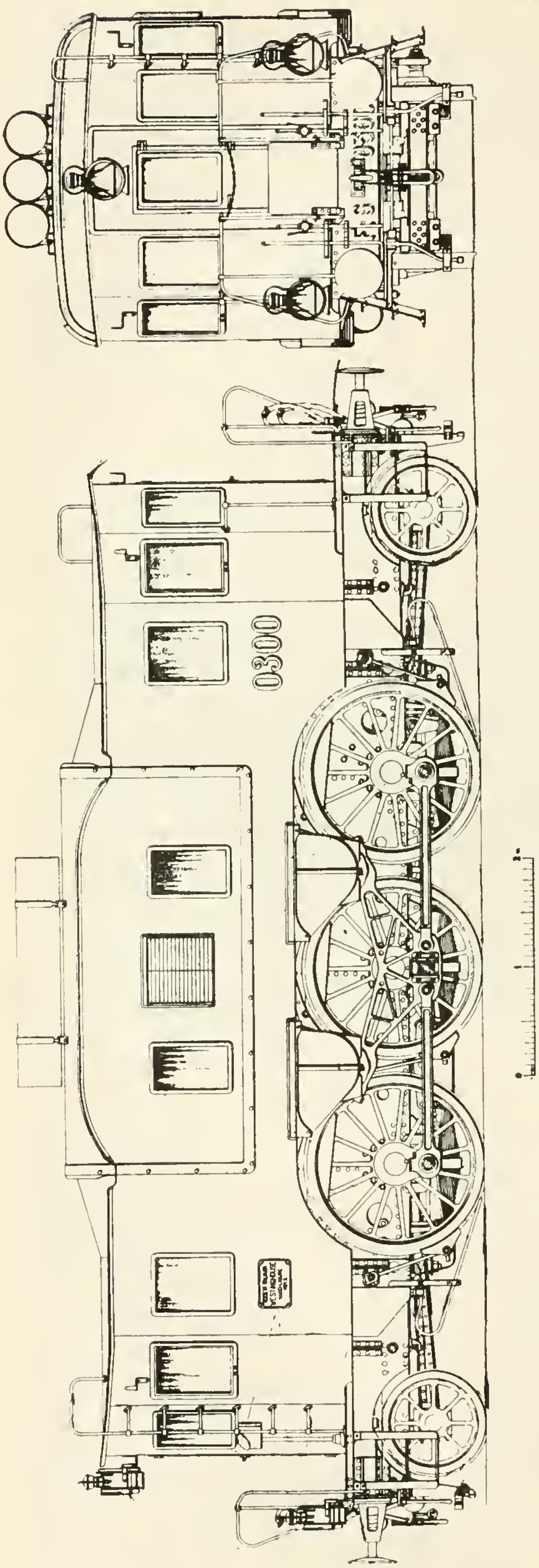


FIG. 3—THREE-PHASE, INDUCTION MOTOR, PASSENGER LOCOMOTIVE, DESIGNED FOR THREE RUNNING SPEEDS

power had to be dissipated in a water rheostat at the power station because it frequently happens that only one train is on the line. At present this surplus energy is used to very good advantage for heating the shop and car barns.

Miscellaneous — As in Germany, the low frequency of 15 cycles does not appear to be objectionable. In fact it was observed that the locomotives on the Loetschberg road show very little vibration Outside of the noise caused by the brushes and the high peripheral commutator speed, the locomotives run absolutely quiet. The motor cars show a certain amount of vibration but neither the passengers nor the engineers of the road seemed to consider these vibrations objectionable.

ITALY

General Situation — The results obtained in Italy with three-phase electrifications appear to be highly satisfactory. The government railroad engineers claim to be able to show considerable saving over steam operation and the result is that a large number of new electrifications are either under construction or contemplated. In consequence, the Italian-Westinghouse Company is turning out locomotives as fast as possible and is being pushed by the government to increase production. It is believed that before long 100 locomotives of the Giovi type will be in operation. A new type of passenger engine designed for three speeds is now under construction. The general arrangement of this engine is shown in Fig. 3, while the latest Giovi freight engine is shown in Fig. 4.

System of Electrification—The adopted standard of electrification for Italy is 15 cycles, three-phase, 3 000 volts, and, as far as could be ascertained, there does not seem to be the least desire for any departure from this system.

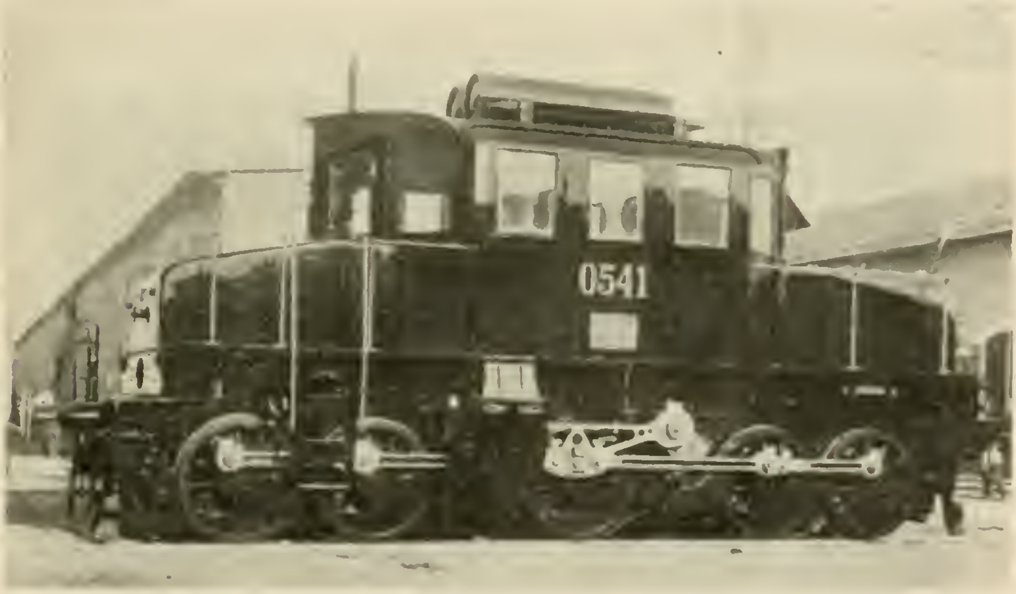


FIG. 4—GIOVI THREE-PHASE FREIGHT LOCOMOTIVE

Mechanical Design of Locomotives—The mechanical design of the Giovi locomotives, which have two gearless motors, a Scotch yoke, side rods and five drivers, is generally considered a success. Although some of the parts of the first locomotives are showing more wear than is desirable, recent experiments have led to the development of proper means to overcome these difficulties. The new locomotives are therefore almost duplicates of the first Giovi locomotives from a mechanical point of view, with the exception of a few minor changes, affecting principally the material of the wearing parts. Some details of the mechanical design are shown in Fig. 5

Motors—The motors of the Giovi locomotives also seem to work satisfactorily. During a visit to the repair shops it was noted that only two or three of the 80 motors were in for repair, a fact which would indicate that the motors give little trouble even after an operating period of three or four years. The motors for the new locomotives will be only slight modifications of the old motors, the principal improvement being a change in the ventilation for the purpose of increasing their capacity.

Auxiliary Apparatus and Control—The auxiliary apparatus and control of the Giovi locomotives has been found satisfactory with only a few exceptions. The principal modification found necessary was the introduction of a circulating pump in connection with the water rheostat. Outside of this only minor changes were made. The electrodes of the water rheostats were changed in the new locomotive to sheet steel instead of cast iron, principally in order to reduce the cost. The master controller and the auxiliary circuits of the control system were somewhat simplified.

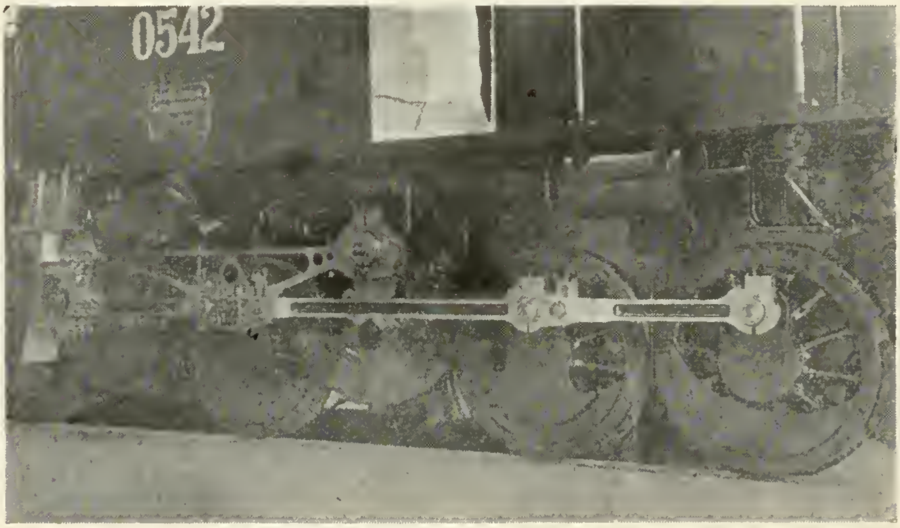


FIG. 5—DETAILS OF DRIVE OF THE GIOVI FREIGHT LOCOMOTIVES

Recuperation of Power—Recuperation of power and electric braking is considered to be of great advantage in connection with three-phase railway locomotives. The locomotives, as operated, are always recuperating when going down the grades, and the saving accomplished in power, wear of brake shoes, wheels and rails, is quite appreciable. In consequence of the high efficiency of the three-phase motors and the absence of any other power consuming apparatus, like transformers, etc., the amount of recuperated energy is very high. It was observed, for instance, that the power recuperated going down grade with a certain train was as high as 60 to 80 percent of the power consumed going up the same grade with the same train. It was also observed that with the operating conditions of the Giovi line, there is very seldom any power wasted by the water rheostats in the power station. It was stated at the power station that this water rheostat is used only about four times a day and altogether not longer than about 20 minutes per day.

Miscellaneous—The double overhead wire and the double pantagraph do not seem to give any undue amount of trouble. The standard pantagraph adopted on the Italian roads is shown in Fig. 6, and one of the air switches is shown in Fig. 7.

FRANCE

General Situation—The principal electrification of France is that of the Midi Railways on their line, Perpignon Ville-franche, which is yet in the experimental stage. This railroad at first made the same mistake as the Prussian government by permitting too much liberty in the designs. The result was that six locomotives were furnished, all of which were very much different with regard to general design as well as details. When these locomotives arrived for tests the railroad company apparently realized the difficulty of keeping this large variety of apparatus in running order. They therefore canceled the order for three of the locomotives on the ground that the delivery of the locomotives and the completion of experimental tests were not in line with the contract. Consequently the three locomotives on the ground are those furnished by the French-Westinghouse Company, the French Thompson-Houston Works and by the Jeumont Works. Besides these locomotives

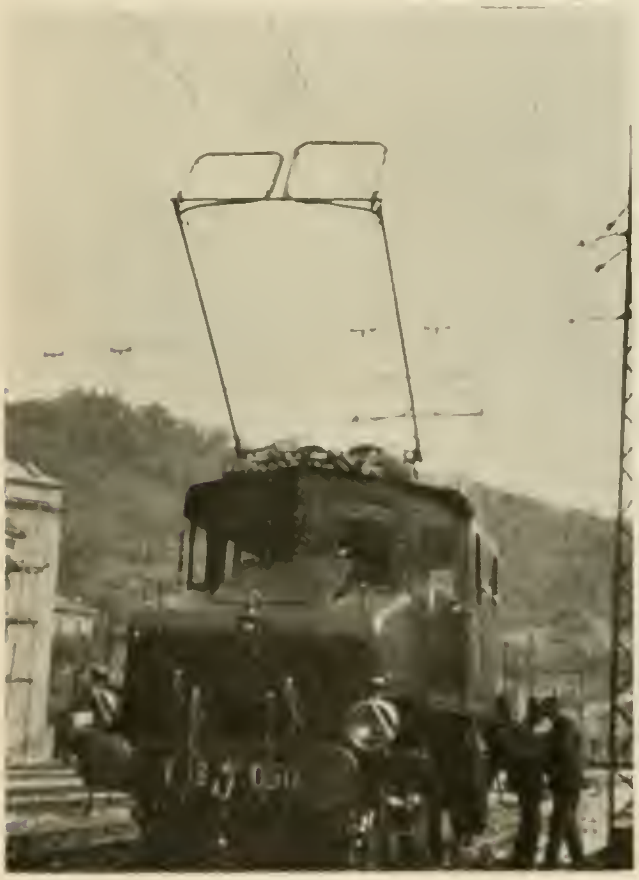


FIG. 6—STANDARD PANTAGRAPH USED ON THE ITALIAN THREE-PHASE LOCOMOTIVES

a number of motor cars furnished by the French-Westinghouse Company are in operation.

System of Electrification—At present the single-phase system, at 15 cycles, 10 000 or 15 000 volts, is considered the standard for the trunk lines in France. There seems to be some uncertainty among the engineers, however, as to whether this system will be finally adopted as standard. In fact, it seems to be the practice to work up competitive propositions for single-phase, three-phase and high voltage direct current. Altogether it seems that in France the electrical manufacturers and engineers are not very self-confident with regard to their own analyses, but are rather inclined to follow the American and German lead.

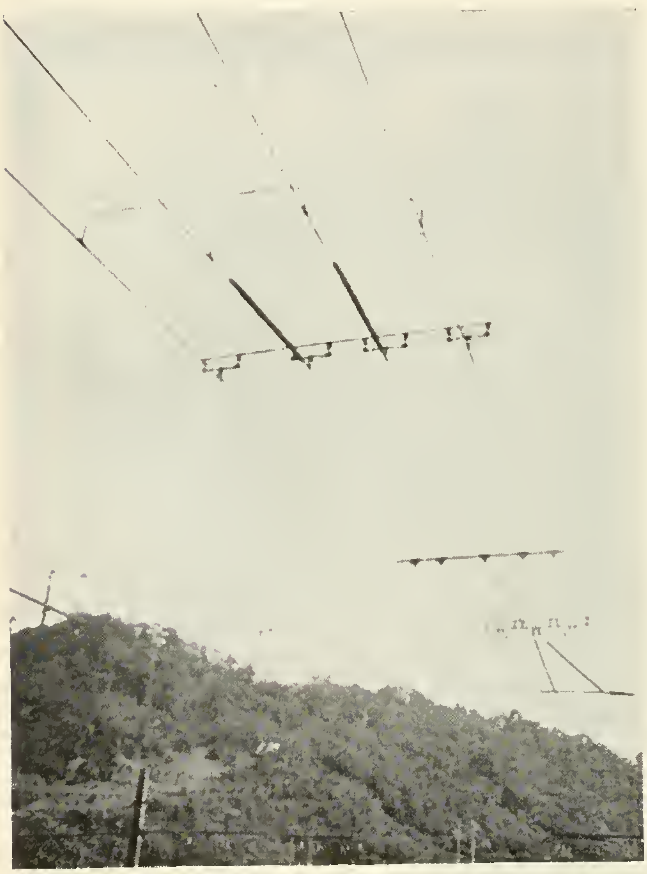


FIG. 7—OVERHEAD SWITCHES ON THE DOUBLE OVERHEAD TROLLEYS OF THE THREE-PHASE ITALIAN SYSTEM

Mechanical Design of Locomotives—The three locomotives on the Midi Railway have the following principal features:—

1—The locomotive of the French-Westinghouse Company has gears and Scotch yoke. The mechanical parts, especially the bearings of this locomotive, have given some difficulty in the beginning, but these difficulties have apparently been overcome by change of the bearing material. At the present time the mechanical parts of this locomotive are considered entirely satisfactory after a service of about 4 000 miles.

2—The Thompson-Houston locomotive has two large motors driving two jackshafts by side rods which are inclined about 45 degrees. The mechanical parts of this locomotive are fairly heavy and have given satisfactory results up to the present.

3—The Jeumont locomotive is, in its mechanical construction, quite similar to the flexible drive of the New York, New Haven and Hartford freight and switching locomotives. The spring drive itself, while accomplishing the same result as on these locomotives, is somewhat different in construction. This locomotive is shown in Fig. 8.

Motors—The straight single-phase motors with resistance leads on the locomotive, as well as the Westinghouse motor cars, are considered very satisfactory. Both the French Thompson-Houston and the Jeumont motors are doubly fed series motors, very similar to the Alexanderson type of the General Electric Company. In both cases, centrifugal devices have been employed to change the motor over from a repulsion motor to a doubly-fed series motor at a certain speed. This arrangement, in connection with this type of motor, seems to work satisfactorily on locomotives. The commutators of all the motors indicate that the commutating characteristics are quite satisfactory.

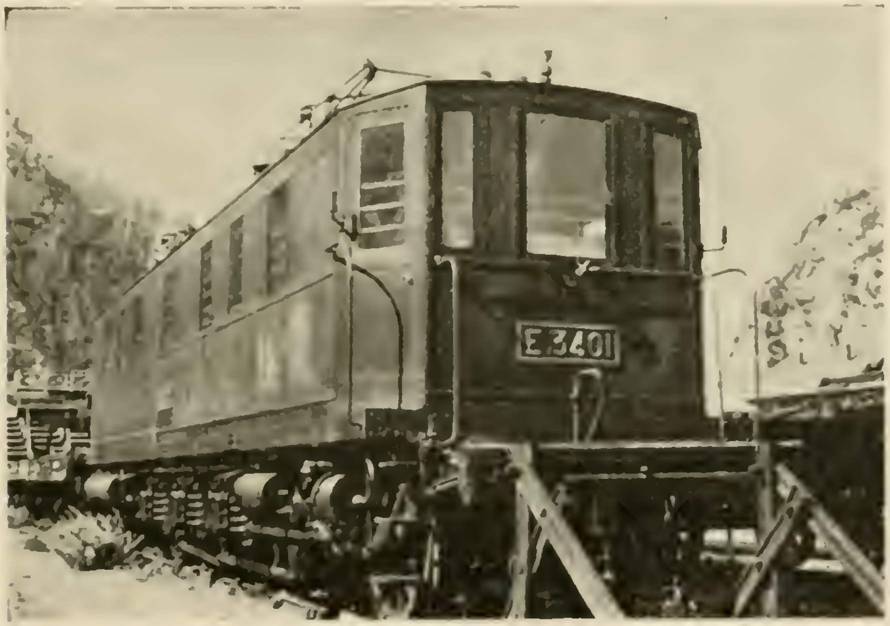


FIG. 8—SINGLE-PHASE LOCOMOTIVE ON THE MIDI RAILWAY

Auxiliary Apparatus and Control—The auxiliary apparatus and control of the French-Westinghouse locomotive appeared to be decidedly superior with regard to simplicity and operating results. The Thompson-Houston control apparatus, while working satisfactorily, appears to be much more complicated and heavier. The control part of the Jeumont locomotive made the impression of a somewhat complicated laboratory arrangement rather than that of an arrangement designed to operate a locomotive. The motor speeds of this locomotive are controlled by means of an induction regulator and drum switches, and the locomotive has a total of some ten motors for operating the various devices. If it is considered that smooth acceleration can be obtained by a number of unit switches, it seems absurd to introduce an induction regulator and all its consequent auxiliary apparatus. The control apparatus of the Jeumont locomotive is said to have operated satisfactorily as long as their engineer stayed with the locomotive. The locomotive has been inoperative most of the time since it has been turned over to the railroad company, principally due to failures of the control.

Recuperation of Power—All of the Midi locomotives are arranged for recuperation or at least for electrical braking, since the railroad company considers the saving of brake shoes, wheels and rails made possible with electric braking of prime importance.

The locomotive of the French-Westinghouse Company was originally designed for recuperation and a number of experimental runs were made. Since the time was, however, too limited to affect the proper adjustments and since the railroad company did not require recuperation, the locomotives were changed over for electrical braking only.

The recuperation scheme of the Thompson-Houston locomotive does not appear to be a very desirable one, as it requires a very heavy induction coil, a heavy extra transformer and extra resistances. Moreover, it is found that the losses in these parts and in the other apparatus of the locomotive are so great that practically no power is recuperated and that hardly anything but electrical braking is accomplished, in a manner much more complicated than in the case of the Westinghouse locomotive. This scheme will probably not be duplicated in the future.

The recuperation scheme of the Jeumont locomotive is working very satisfactorily. This scheme necessitates a couple of small exciting motors, which, however, do not mean much extra weight because they are used at the same time for driving the compressor and the blower. The use of an extra exciting motor instead of using one of the traction motors for excitation, as in the Westinghouse scheme, is advantageous, as it leaves the full rating of the traction motors for the purpose of braking and also because it gives great ease for properly regulating the excitation.

The French-Westinghouse locomotive is at present considered to be the most desirable and orders have recently been given for additional equipment.

SUMMARY

General Situation—A general review gives the impression that many things in Europe are about to, or probably will in the future, follow the American lead, and that a large number of arrangements which in the past have been considered undesirable in this country are being discarded in Europe.

System of Electrification—With the exception of the three-phase installation by the Italian-Westinghouse Company, it seems that the single-phase system is being adopted all over Europe. It is to be noted, however, that the European roads are using a frequency of 15 instead of 25 cycles. During the writer's visit the news of the phase converter locomotive, as proposed for the Norfolk & Western, had not reached Europe. The introduction of this type of locomotive may, of course, have some influence upon the choice of system and frequency as well.

Mechanical Design of Locomotives—The only European locomotives which have been successful from a mechanical point of view and which give at the same time reasonable weights use either gear arrangements or the Scotch yoke construction, or both, and even in Germany it seems that the gear arrangements will be used, in spite of much opposition.

Motors—All repulsion and Winter-Eichberg motors are being abandoned, and the series motor is coming into general use.

Auxiliary Apparatus and Control—The general tendency is now towards simple unit-switch control. All schemes using induction regulators or brush shifting are about to be abandoned for trunk line work.

Recuperation of Power—On the three-phase systems, the results obtained have been exceedingly satisfactory. Two schemes for recuperation on the single-phase system have met with some success, indicating that results may be expected along this line in the future. At present it seems, however, that the phase converter locomotive is superior to either of the two systems mentioned above where recuperation is of importance.

THE SELECTION OF ELECTRIC LOCOMOTIVES

L. M. ASPINWALL

IN THE PRESENT state of the art of electric locomotive building it is not necessary to ask the question, "Will it do the work as well as a steam locomotive?" as any doubt can be set at rest in the most satisfactory manner by an inspection of some of the many installations where the electric locomotives are daily performing the work previously done by steam locomotives. Before selecting an electric locomotive, however, it is essential that careful consideration be given to the determination of the type of machine best suited to the conditions, as the future success of installation depends largely on the good judgment exercised in this selection.

Generally speaking, locomotive service can be divided into three general classes: switching, interurban and main trunk line service In switching service the locomotive is used to haul cars in the yards of an industrial plant, in railroad terminals or equivalent service; for interurban service the locomotive should be suitable for general light haulage on trolley lines between cities, usually in connection with passenger car service; while main trunk line locomotives are used to haul freight or passenger trains equivalent to those handled by steam locomotives on the main arteries of traffic between the great commercial centers. Each one of these classes calls for a different type of locomotive in order to perform the service in the most efficient manner. Knowing the class of service required of a locomotive, it is then necessary to lay out the service conditions in such a manner that the capacity of the machine required can readily be determined.

SWITCHING SERVICE

If the locomotive is to be used for switching service the general essential characteristics are as follows:—

1—High tractive effort relative to the output.
2—Moderate speed.
3—Sufficient weight to handle the maximum train.
4—Running gear adapted to negotiate poor track conditions and capable of rounding sharp curves.
5—Cab constructed to give a clear view of the track for either direction of operation.
6—Current collectors which permit the operation of the locomotive in either direction without attention.

Tractive Effort and Speed—In order to obtain the condition of high tractive effort, it is generally necessary to employ the maximum gear reduction which can be used on commercial motors, and this reduction will generally fulfill the second requirement of moderate speed. The lower the speed at which a given train is handled, the lower the peak load will be on the power house; but it should be remembered that even for switching service it is not desirable to carry the idea of low speed to extremes, as it is quite possible to have the speed of a locomotive so low that it could not be used for making "flying switches" or for "kicking cars," as is often essential in switching service. For this reason locomotives with special double reduction gearing are not to be recommended, except under peculiar conditions.

The Required Weight of a switching locomotive is determined in the same manner as it is for other kinds of service, that is by the maximum train to be handled and the track conditions where the locomotive is to be operated. If the locomotive is to operate on level track only, a rough and ready method of determining the required locomotive weight is to multiply the weight in tons of the maximum train to be handled by 0.04 and the result will give the weight in tons of the locomotive which will be required to start and accelerate the assumed maximum train at approximately one-tenth of a mile per hour per second on a straight, level track. If the locomotive is to be used to handle cars over a "switching hump" or on other grades, due allowance should be made, and the weight of the locomotive increased in proportion.

Running Gear—The simplest form of running gear that can be built is the two-axle rigid frame type. This consists of two axles running in journals which are carried in pedestals, secured rigidly to the locomotive frame. Where only a few cars are to be handled and where the curves to be negotiated are of generous radius, this type of locomotive can be used advantageously. This is certainly the cheapest form of machine that can be produced. However, average switching service, up to and including the heaviest classes of this work, is usually best handled by a locomotive of the well-known swivel-truck type. This type of locomotive allows great flexibility of equipment and can be built for practically any ordinary conditions of switching service.

Cab Construction—Long experience has shown that the best form of cab for an electric switching locomotive is the well-known "Steeple Type." This construction embodies a full height of cab in the center of the locomotive and short sloping hoods at each end. It was formerly the practice to make the center of the cab comparatively short and the hoods of generous proportions, so that all of the apparatus could be located in them. This latter arrangement had the advantage of leaving the central cab clear of apparatus, but it has been found by experience that this advantage is far outweighed by the disadvantage of having the apparatus under the hoods where it was relatively inaccesible and usually considerably crowded. The best accepted practice is to make the main cab of ample dimensions, so that the apparatus can all be mounted in it in such a manner as to be thoroughly accessible from all sides; and to make use of the small end hoods for the compressors (and the blowers when they are used), the noise of which is more or less objectionable in the main cab. This arrangement places the apparatus where it is under the eye of the motorman or attendant at all times and where it can easily be inspected and overhauled. A photographic view of a typical modern switching locomotive is shown in Fig. 1.

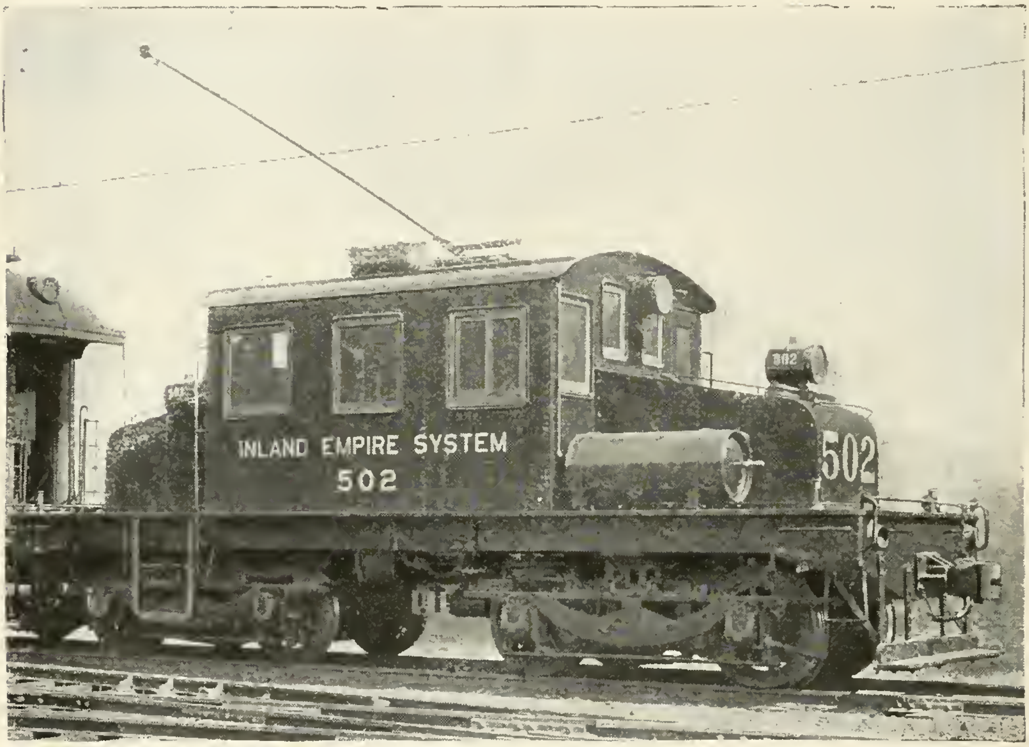


FIG. 1—SWIVEL TRUCK ELECTRIC LOCOMOTIVE
For switching and light freight service.

The Current Collectors for a switching locomotive are a very important item, as a great deal of time is wasted if the collector requires constant attention. Undoubtedly the best form of collector which has been developed for this service with overhead construction is the pneumatically-operated pantagraph trolley. Such a collector, mounted on a switching locomotive, is shown in Fig 2. In order to be able to use this type of collector it is essential that the overhead construction be installed in such a manner as to permit the use of a sliding contact. It frequently happens that the locomotive must also be able to operate between several switching yards where standard overhead trolley construction is used and, in such cases, it is necessary to add a wheel trolley in addition to the pantagraph.

Brakes—If the locomotive is only to handle a few cars, and brakes are to be used on the locomotive only, the simple "straight air brake" will be the cheapest and simplest to install. If the locomotive is to handle trains of considerable size and the brakes are to be operated on the cars, an "automatic air brake" is essential

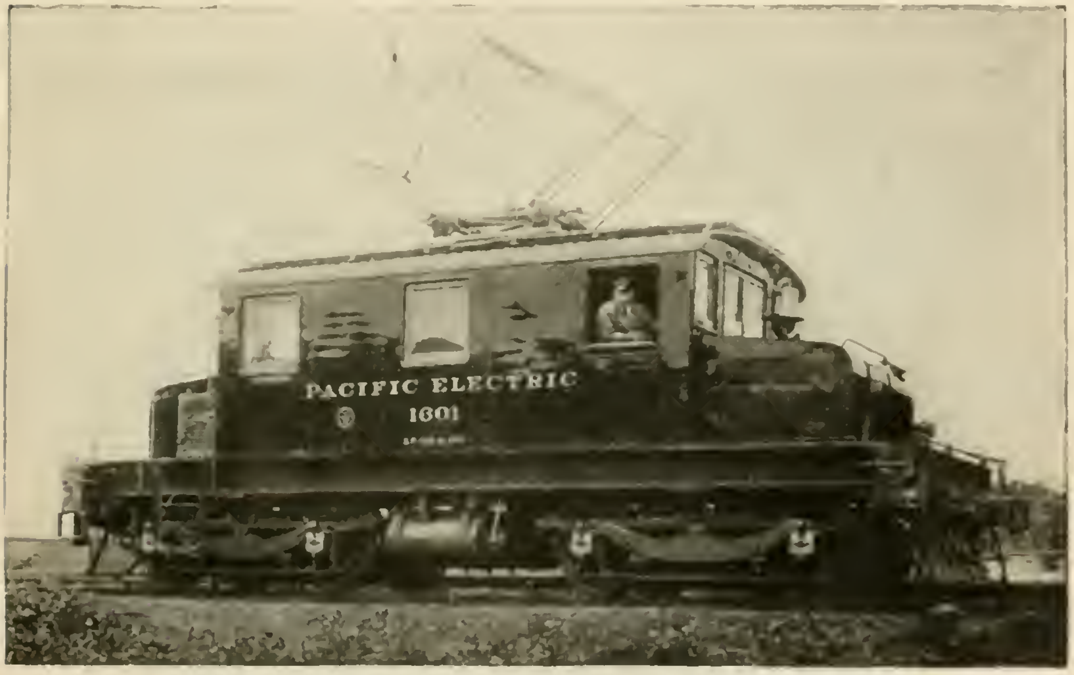


FIG. 2 SWITCHING LOCOMOTIVE EQUIPPED WITH PANTAGRAPH TROLLEY

INTERURBAN LOCOMOTIVES

It is frequently found that interurban trolley lines increase their earnings by the handling of light freight traffic in addition to passenger service. There is, therefore, a demand for locomotives of medium size which can handle light weight trains at a fairly high speed under standard trolley line construction. Such machines are generally classed under the head of interurban locomotives. Their essential characteristics are as follows:—

1—Moderate tractive effort relative to the output.

2—Comparatively high speeds.

3—Sufficient weight to handle maximum trains of seven or eight cars.

4—Running gear suitable for safe operation at maximum speeds of 40 miles per hour.

5—Current collectors capable of operation with standard trolley construction, and capable of collecting comparatively large currents.

Speed—Locomotives used in this class of service must operate either between passenger cars in the regular daily service or must operate at night when the passenger service is infrequent, but in either case they must have sufficiently high speed to enable them to keep out of the way of the passenger cars. This generally means that the locomotive is geared so as to operate light at a maximum speed of about forty miles per hour.

Running Gear—The swivel truck type of running gear is suitable for locomotives of this class where maximum speeds of not more than forty miles per hour are required, but it is desirable to have a greater distance between truck centers than is employed in switching service in order to give better riding qualities.

There is no sharp dividing line betwen this type of locomotive and the switcher locomotive, the principal difference usually being in the gear ratio, the truck wheel base, and the distance between truck centers. It quite frequently happens that the switching service and the interurban service, on a given line, are such that a locomotive can be selected of such dimensions, capacity and gear ratio that it can be used as an all around road unit with satisfactory results. Occasionally an interurban line forms a connectinig link between steam lines and a locomotive is required to handle a few passenger cars at a high schedule speed requiring a maximum of sixty miles per hour or more. In a case of this kind it is ad-

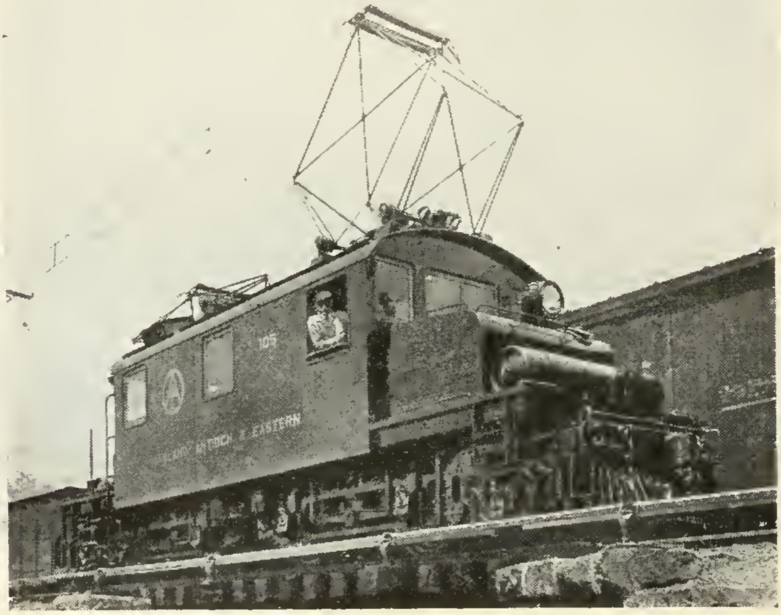


FIG. 3—HIGH SPEED PASSENGER LOCOMOTIVE
This machine is capable of operating at speeds up to seventy miles per hour.

visable to provide the locomotive trucks with pony wheels, so as to insure better tracking characteristics at high speed. A locomotive of this type is shown in Fig. 3.

In order to handle seven or eight freight cars at a speed of twenty or thirty miles per hour on level track, maximum currents of 700 amperes or more will have to be taken from the line during acceleration, and it is thus frequently necessary to use two trolley wheels in tandem. The air brake equipments should be of the automatic type and the compressors of ample capacity to handle the brakes on all the cars in the maximum train.

The remarks relative to cabs and the arrangement of apparatus on switcher locomotives apply equally well to machines of the interurban class.

MAIN TRUNK LINE LOCOMOTIVES

When locomotives suitable for main trunk line service are considered, the field is so large and the conditions so diversified that it is impossible in a short space to more than touch on a few of the important features.

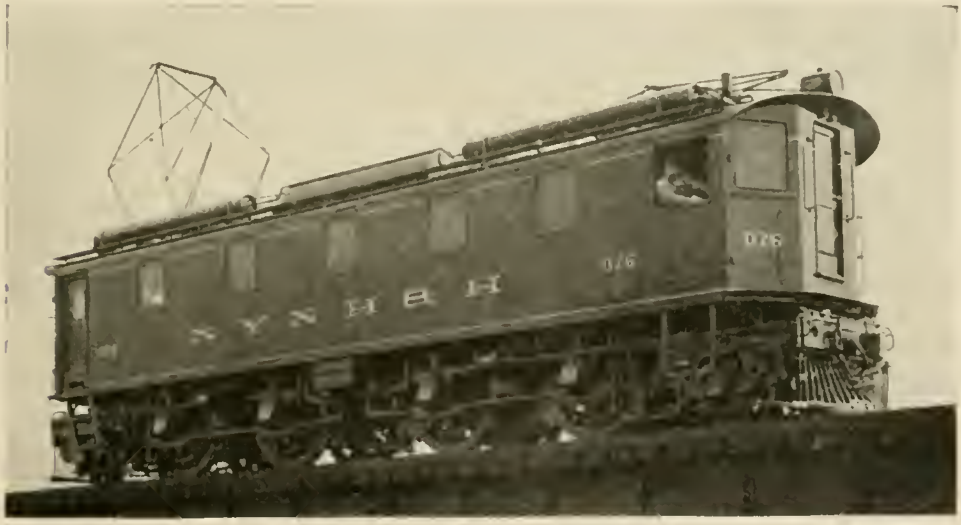


FIG. 4—TYPE OF LOCOMOTIVE SUITABLE FOR BOTH HIGH SPEED FREIGHT AND PASSENGER SERVICE

Main line service can be divided broadly into freight, passenger and pusher service. For average freight service conditions on a main line, a locomotive should be able to haul trains of 1 500 tons or more, operate at maximum speeds of approximately fifty miles per hour, and be in general of very rugged construction so as to stand up under severe service conditions.

On account of the heavy draw-bar pulls which have to be exerted by such locomotives, it is common practice to construct them with articulated trucks; that is, trucks which are coupled together and which are provided with couplings for connecting directly to the train, so that the draw-bar pull does not have to be exerted through the center pins and cab framing. Where the locomotives are to be used only for slow freight service two trucks, each provided with two driving axles, usually constitute a satisfactory arrangement of running gear. If they are to be used in fast freight service, guiding or pony wheels should be added on the trucks.

Sometimes the conditions of freight and passenger service are such that an all-around locomotive can be used with fairly satisfactory results for both classes of service; this, however, is the exception. As a usual thing if a locomotive is geared for high enough speed to meet with the passenger service requirements and at the same time is capable of giving the maximum draw-bar pull required for freight service, the size and capacity necessary is prohibitive. There is no sharp line of distinction between the running gear of a high-speed freight locomotive and that of a passenger locomotive, and in fact several different forms have been developed which can be used advantageously for either class of service with suitable equipment. A locomotive of a type which is admirably suited for either freight or passenger service is shown in Fig. 4. This can fairly be considered as typical of the best form of main line locomotive being constructed today.

On account of the size and capacity of the motors and control equipment it is generally found advisable to use the full length of cab (or box cab, as it is termed) in order to house this apparatus properly. The central arrangement of apparatus with a compartment for the engine driver in either end of the cab has proved most advantageous.

No attempt has been made in this article to discuss the merits of the various systems extant, as applied to the different classes of service, as so many different conditions enter into the problem that each case should be considered individually. As far as the locomotive itself is concerned, it has been demonstrated that either the direct-current or the single-phase equipment is able to handle the most severe conditions of service that are encountered in modern steam locomotive practice.

INSPECTION OF RAILWAY APPARATUS

L. E. SCHUMACHER,

Chief Inspector, Westinghouse Electric & Mfg., Company

IN order to insure the successful operation of railway apparatus after it is installed and put into operation, careful inspection is necessary throughout the process of manufacture. In large manufacturing concerns the duty and responsibility of seeing that all materials and parts are properly inspected is usually delegated to a separate department known as the inspection department. This department is composed of men who have had considerable practical experience, not only in the manufacture, but also in the operation of products.

For the inspection of electric railway equipment it is customary to select men from the winding and machining departments of the factory, from operating companies and from other manufacturers of railway apparatus. Inspection work may be sub-divided into several sections, such as, raw materials inspection, coil assembling and insulation, and the machining of parts and assembling for final shipment. The inspectors in charge of these divisions report directly to the foreman of inspectors whose duty it is to keep in close touch with all parts of the apparatus handled in his division, and take up any questionable points that may come up, with the sales, engineering or works departments. The foremen of inspectors report to the chief inspector.

In outlining methods of inspection, the practice of the company with which the writer is connected has been used to a certain extent as a means of indicating the great variety of detail work required of an inspection department.

RAILWAY MOTORS

In taking up the inspection of raw materials for railway motors, all of the material, except axle steel, is inspected on its arrival at the works, and checked with the specifications and information from which it is ordered. The axle steel is inspected at the supplier's plant, and physical and chemical tests are made and forwarded to the inspector for approval, before this material is shipped.

Copper coils are made on formers, then checked to dimensions, and are given an insulation test before the winding operations in order to insure their satisfactory operation after being assembled in the apparatus. In the inspection of the machining operations, it is necessary to have first class mechanics as inspectors in order to be sure that the machined parts, such as frames, housings, etc., are accurately machined to proper dimensions.

In the inspection of frames, the bore is checked carefully to be sure that the motor will have the correct air-gap when finally assembled. The bores for the housings are also checked carefully, this point being of special importance on split-type motors. The drilling of the frame in regard to location of stud holes and wire cleat bolt holes is checked carefully, as this has a direct bearing on the running of the motor on the neutral point and the proper anchoring of the cables.

Gear cases are checked for fit along the parting lines and the clamping fit on the supports. Each gear case is fitted to a motor which has been checked, and the clearance inside for gear and pinion is checked with a gauge. In checking up the housings, the bore is checked carefully to insure that the bearings will fit tight for outside diameter. This is to insure a tight fit of the gearing and the distance from the bearing collar to flange is checked so that the armature will have the proper amount of end play. All of the housings are examined carefully for leaks with carbon oil.

Bearings are checked carefully for outside diameter to insure a tight fit in the housing; the collar thickness also being checked, as this governs the end play, and each bearing is gone over after it has been babbitted and the bore checked for size with a plug gauge. Particular attention is paid to the condition of the babbitt, samples being taken from the babbitt pots at regular intervals, and forwarded to the chemical laboratory, where tests of the samples are made and the condition of the babbitt reported.

In turning up and grinding off the shafts, the diameter of the journals and all fits are checked carefully by the inspector, special attention being given to the taper fit for the pinion. The taper fit for the pinion is ground to gauge, and each individual fit is checked with a gauge and ink. The threads for the pinion nut receive special attention, being machined over size and finished to size with a hand die after the motor has been completely assembled and tested. It has been found that this practice has eliminated practically all trouble with loose pinion nuts.

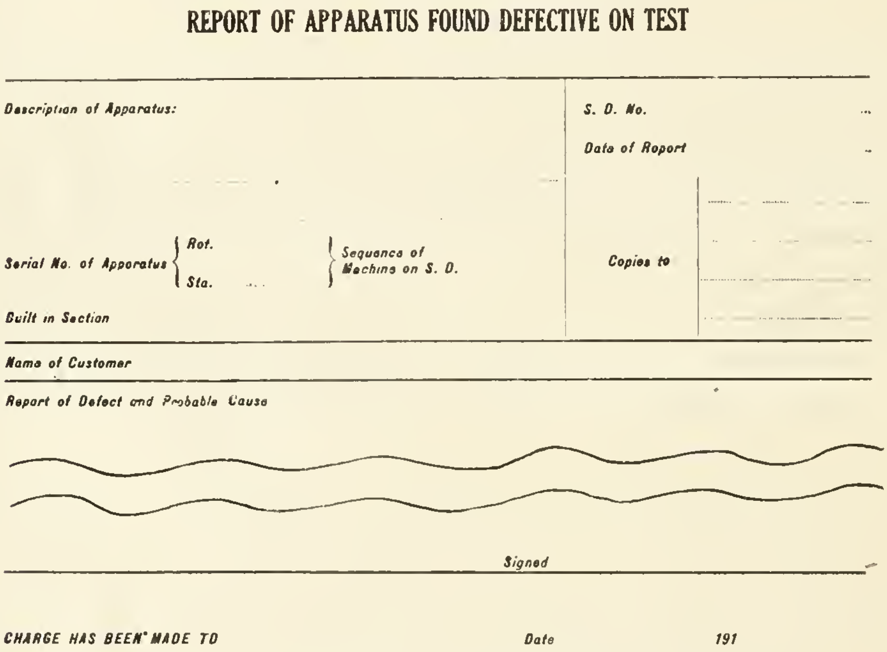
In checking up the armature spiders, the bore is checked by the inspector to correspond to the size shaft required, and also as a means of determining the proper tons pressure for pressing on the shaft. The outside diameter of the spider is ground according to the size of the die used to punch the laminations. Special attention is paid in the building up of the laminations to make them as tight as possible on the spider or shaft, and to provide the proper clearance for the insulation on the end bells and coil supports. After the iron has been built on the spider or shaft, it is inspected for projecting laminations and the corners at the end of the slots rounded. After this, all cores are balanced and the shaft tested to make sure that it is perfectly straight.

In winding of the armatures, the inspector checks up the actual operation of winding and connecting to prevent excessive pounding of the insulation by workmen or the use of metal drifts in driving the coils into place in the slots. This is an important point, as any nicks are liable to cause the breaking of the leads, due to vibration. The inspector also checks armatures for length between journals, and the distance from rear wiper ring to front of commutator bar, and the diameter of the banding over the winding. The bands over the winding must not exceed the diameter of the armature iron, and are all checked for size; also for soldering. After the armatures are completed they are all given a test for short circuit and open circuit before being forwarded from the winding department to the assembling department.

In the building of commutators, the mechanical checking consists in checking the bore of the ring and bush with pin gauges, the checking of the angles of the V's on the ring and bush with gauges, the checking of the over-all length of the assembled commutator, the thickness of the necks, commutator bars and the outside diameter of the neck and brush face of the commutator. The inspector also notes the alignment of the bars with the center line of the bore, the position of the bars with regards to the keyway, the size of the slots in the necks, and their position as regards proximity to the edge of the bar. Each commutator is also given a ground test and test for short circuits between bars before it is shipped from the commutator department.

In the assembling department an inspection is made of the condition of the inside of the frame casting, as regards rough spots and proper coil clearance, before the coils are assembled in the frame. After the coils are assembled another inspection is made which checks the anchoring of the cables, the position of the brush-holders in relation to the center of the poles, the condition of the coils as regards proper spring tension to hold them solidly against the poles; also the general condition of the wiring, taping and banding. After the armature is assembled in the frame, a check is made to be sure that the armature turns freely in the bearings, the end play is not excessive, the brush holders have the proper clearance over the commutator necks, and that the commutator bush or ring clears the end housings enough to allow the proper end play.

After the motors are assembled they are forwarded to the testing department, where each motor is tested and, after being passed as satisfactory, returned to the finishing stands, where an inspection is made covering the fit and alignment of the axle bearings, the proper application of pinions, both as regards size of pinions and workmanship, and a test for loose brush holders. A check for the proper gear case clearance is made at this time by applying a test gear case.



REPORT OF APPARATUS FOUND DEFECTIVE ON TEST

Description of Apparatus:

S. O. No.

Date of Report

Serial No. of Apparatus { *Rot.* / *Sta.*

Sequence of Machine on S. O.

Copies to

Built in Section

Name of Customer

Report of Defect and Probable Cause

Signed

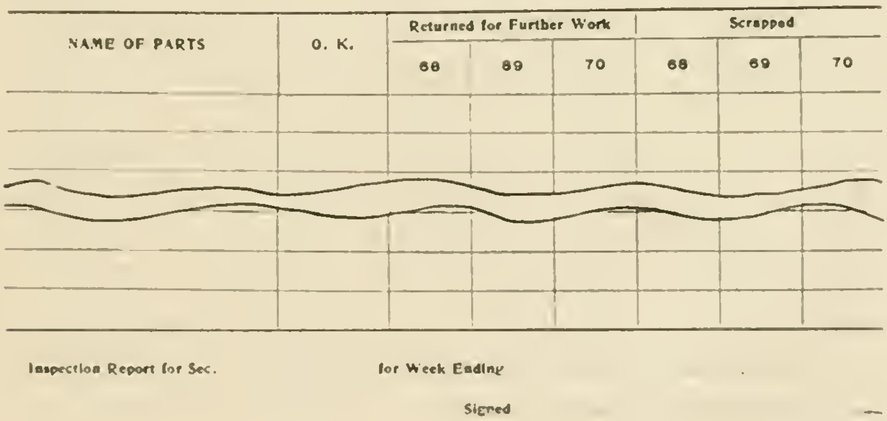
CHARGE HAS BEEN MADE TO *Date* *191*

FIG. 1—FORM OF REPORT FOR APPARATUS FOUND DEFECTIVE.

Before the motor is shipped from the finishing stand, it is gone over by the inspector and a final check taken in accordance with the information on the stock order. All information in regard to apparatus returned to the manufacturing sections for further work, etc., is tabulated on a report form such as shown in Fig. 1. This is turned over to the foreman of inspectors, who forwards it to the inspection office, where it is tabulated on a larger form, Fig. 2, and forwarded to the superintendent of the department interested. This keeps the superintendent in close touch with the number of pieces returned on account of defects or uncompleted work.

SWITCH GROUPS

In the inspection of switch groups and line switches, the machining of the frame is carefully checked in regard to the depth and position of the air supply holes; also to be sure that the frame is machined square, and that the overall length is exact. The base plates are checked for overall length and for the correct thickness; this being necessary as the proper contact between the switch and the terminal bolt depends on the thickness of the base plate. Each cylinder is checked for depth of bore with special gauges for this work, and gone over to be sure that the surface of the bore is smooth, as the life of the leather and efficiency of the cylinder depends on this point.



NAME OF PARTS	O. K.	Returned for Further Work			Scrapped		
		68	69	70	68	69	70

Inspection Report for Sec. for Week Ending

Signed

FIG. 2—FORM FOR SUMMARIZING REPORTS FOR AN ENTIRE SECTION

Magnet brackets are checked carefully in regard to the location and depth of the holes for the valve bushings. The suspension surface is checked for accurate machining, for if this is not correct the magnet end will not engage the angle support on the front of the group properly, and is very liable to break the bracket or cause an air leak. The magnet bracket is then given a careful test for air leaks and magnets are checked for operation at the proper voltage. The air-gap is not allowed to vary more than plus or minus 0.001 inch, thereby insuring the correct operation of the magnet. The travel of the piston is checked carefully with special gauges, as this point is directly responsible for the proper contact between the switch jaws.

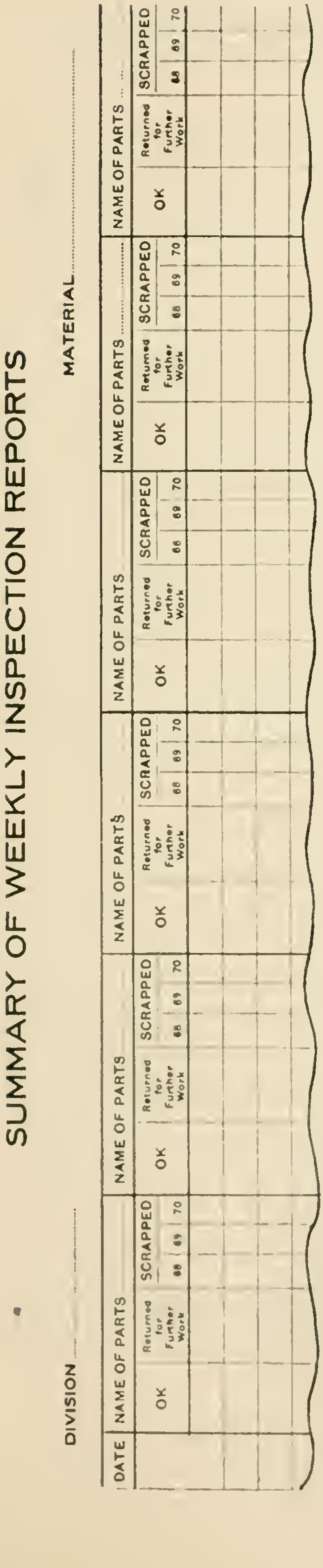
In checking the switches, special gauges are used for checking the drilling and machining of all switch parts. This insures satisfactory operation after the switches have been assembled. The switch groups and line switches are inspected at different times during the process of assembling, and after being assembled the control wiring is checked both as to the location of the wires and the marking of the terminal clips. The groups are given an insulation test and then forwarded to the testing department, where each is tested and, if satisfactory, returned to the manufacturing section, where it is inspected for the proper fitting of covers, marking, painting, etc.

CONTROLLERS

In inspecting the master controllers, particular attention is paid to the overall dimension from top of the base to the bearing for the shaft on the bottom in order to be sure that there is no lost motion in the drum. The drilling of all holes for holding the finger board is checked to make sure that the fingers have the required pressure on the drum. After assembling, a general inspection is given the finished controller to insure the correct mechanical operation. In checking the jumpers and receptacles, each jumper and receptacle is inserted in a master receptacle or jumper head and lighted out, to be sure that the leads are connected properly. Before they are turned into stock, they are also given the same insulation test as the switch groups.

LOCOMOTIVES

A number of inspectors are required to take care of the inspection of the mechanical parts of mining and main line locomotives. These inspectors check up each part of the locomotive during the process of manufacture. On the larger locomotives, after the mechanical parts have been completed and checked by inspectors, the electrical apparatus is installed. Before beginning work on the electrical equipment, a general inspection is made for missing parts, etc., the condition of the journals noted, gears inspected, the wheels and axles of trucks of the quill drive type have the wheels and axles removed, and checked for the proper tire tread, and correct clearance of the pedestal boxes. The wheels are also checked at this time for quartering to insure the proper distribution of the strains. The draw-bars are checked to insure the correct height and proper clearance. After the cab is placed on the trucks, and the electrical



SUMMARY OF WEEKLY INSPECTION REPORTS

DIVISION ____________ MATERIAL ____________

DATE	NAME OF PARTS		SCRAPPED			NAME OF PARTS		SCRAPPED			NAME OF PARTS		SCRAPPED			NAME OF PARTS		SCRAPPED			NAME OF PARTS		SCRAPPED		
	OK	Returned for Further Work	68	69	70	OK	Returned for Further Work	68	69	70	OK	Returned for Further Work	68	69	70	OK	Returned for Further Work	68	69	70	OK	Returned for Further Work	68	69	70

FIG. 3—A FORM OF WEEKLY INSPECTION REPORT.

equipment installed, the brake rigging, air piping and conduit is gone over carefully, all wiring is gone over and checked out, and the finished cab is given a final and complete inspection. Before the locomotive is turned over for test, the air brake system is tested, and the control system is checked by going through a sequence of switches, noting the correct operation of each individual piece of apparatus. The locomotive is then given an insulation test and turned over to the testing department. After the locomotive has been returned as satisfactory, it is gone over again to check up any defect that may have developed during test, and another test is made on the air system. After this is done a final insulation test is made and the locomotive is ready for shipment.

SUMMARIZING

When apparatus is found defective on test the testing department make out a report such as in Fig. 3; making an original and two carbons. The original is forwarded to the chief inspector's office; one copy is forwarded to the section performing the work, and the other is retained in the testing department for reference. The foreman of inspectors takes up each case of defective apparatus and decides where the defect was due, to defective manufacture or engineering, reporting on his copy of the report which is sent to the inspection office These reports are tabulated on a monthly report, Fig. 4, showing the number of machines found defective on test during the month, due either to defective manufacture or design. A copy of this report is forwarded to all intersted parties

INSPECTION DEPARTMENT

REPORT OF APPARATUS FOUND DEFECTIVE ON TEST

MONTH OF	SECTION B				Insulation	Winding	Bearings	Air Gap	Wrong Parts	High Losses	Wrong Connections	Commutator and Collector	Balancing	Test	Miscellaneous	Total Shop Defects	Total Engineering Defects	Total Shipped	% Defective Shop	% Defective Engineering
	Insulation	Winding	Ratio	Assembling																
B. C. & D.																				
51 A.C. Turbo Generators																				
52 D.C. " "																				
53 A.C. Rev. Fld Type																				
54 Rotary Converters																				
55 Induction Regulators																				
56 Other D.C. Machines																				
57 Induction Motors																				
S. & T.																				
58 A.C. Rev. Fld. Type																				
59 Rotary Converters																				
60 D.C. Machines																				
61 Induction Motors																				
62 Induction Regulators																				
108 D.C. Turbo Generators																				
W.																				
63 D.C. Machines																				
64 Polyphase Motors																				
65 Single-Phase Motors																				
I.																				
101 Small Power Motors																				
A. & F. I.																				
66 D.C. Ry. & Mill Motors																				
67 Mining Motors																				
68 A.C. Ry. Motors																				
69 Compressor Motors																				
70 Multiple-Unit Control																				
71 Drum Controllers																				
104 Miscellaneous Parts																				
P.																				
72 Tranf. (over 50 K. W.)																				
73 " (up to 50 K. W.)																				
74 " Series and Shunt																				
75 Arc Lamp Rectifiers																				
105 Circuit-Breakers																				
106 Lightning Arresters																				
K.																				
76 Solenoid Control																				
77 Face-Plate Control																				
78 Oil Switches																				
79 Circuit-Breakers																				
80 Switchboards																				
81 Heating Apparatus																				
82 Rectifier Bulbs																				
83 Misc. Detail Apparatus																				
84 Line Material																				
91 Auto-Starters																				
107 L. T. Rectifier Outfits																				
R.																				
85 Locomotives																				
86 Locomotive Motors																				
Y.																				
110 Automobile Machines																				

FIG. 4—A FORM OF MONTHLY INSPECTION REPORT

in the engineering and manufacturing departments, in order that they may keep in close touch with the actual condition of the apparatus.

SOME FEATURES IN MOTOR DESIGN FOR LOW FLOOR CARS

F. W. McCLOSKEY

THE design of electrical equipment for low-floor cars had its inception about three years ago, when the Pittsburgh Railways Company equipped one of its trailer cars of the low-floor type with motors and control and placed it in regular service. The design of this equipment presented a number of difficult problems in electrical and mechanical details, all of which were finally worked out for this particular car. During the past three years development has progressed rapidly, and the difficulties relating to the general design have for the most part been overcome. Whatever drawbacks are still present may be considered as being more than balanced by the inherent advantages of this type of car.

The design of the low-floor car is characterized by light weight, simplicity of construction and convenient arrangement for loading and unloading of passengers. As such, it has an advantage over the ordinary types because of the lower cost of maintenance and the saving in power consumption due to its light weight. These advantages are especially marked in city service.

GENERAL LAYOUT

In the low-floor car the space available for the motors is greatly reduced as compared with the standard 33-inch wheel truck, the distance between the rail and the car floor being less than in the ordinary type by 8 to 12 inches. This means that the space for motors is less by an amount varying from 10 to 20 percent. Further, the clearance between the bottom of the motor frame and the rail, being determined by the amount of wheel wear permissible and the clearance required for safety, is normally about the same as in the ordinary type of car. Also the distance between the motor frame and car body, being determined by the space required for brake-rods and facility for inspection of motor brushes, commutator, etc., is also practically the same as in the ordinary types. It is thus apparent that no material gain can be expected from these quarters, and that a motor to fit the requirements must be of considerably smaller barrel* diameter than ordinarily would be the case.

MOTOR EFFICIENCY

The principal factor which determines the electrical efficiency of a railway motor is the amount of copper loss This is particularly true at the hour or nominal rating, which is approximately the rate at which a railway motor takes power while accelerating the car As the accelerating periods in city service constitute a large percentage of the total time of operation, the copper loss during these periods is of prime importance.

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*Maximum outside diameter of motor frame.

Armature—The amount of copper loss in the armature depends very largely upon the diameter. For a given horse-power and armature speed, decreasing the diameter requires a corresponding increase in the length of core, and hence of the copper lying within the core. The effect upon the length of copper extending beyond the core at each end depends upon the particular case considered. For very small diameters the ends of the coils must be greatly extended to obtain sufficient room circumferentially. Also, for large diameters, the ends of coils must be greatly extended because of the long throw of the coil. The relations involved are shown in Fig. 1. On their respective coördinates, 100 percent represents the armature diameter and the total length of armature copper for which the copper loss in the armature winding is a minimum. Curve *C*, representing the relation between armature diameter and total copper required, is obtained by adding the ordinates of curves *A* and *B*. It will be seen from curve *C* that a reduction in diameter of 25 percent below normal (100 percent on the curve) would result in 20 percent greater total length of copper in the armature winding and a corresponding increase in copper loss.

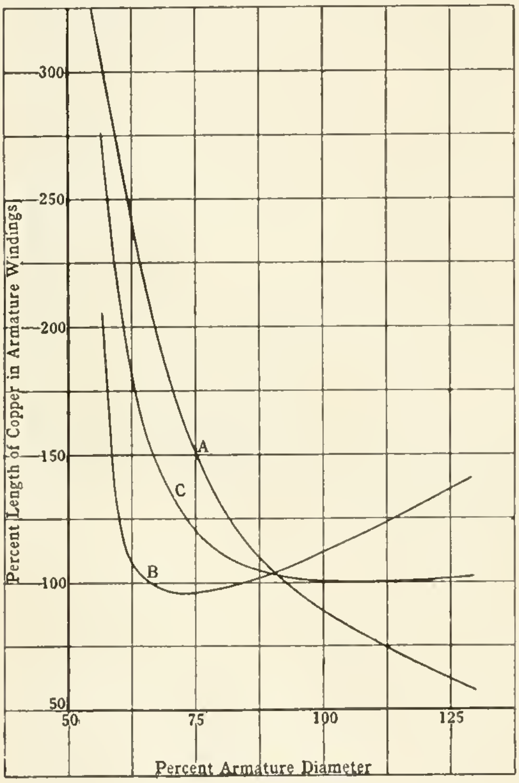
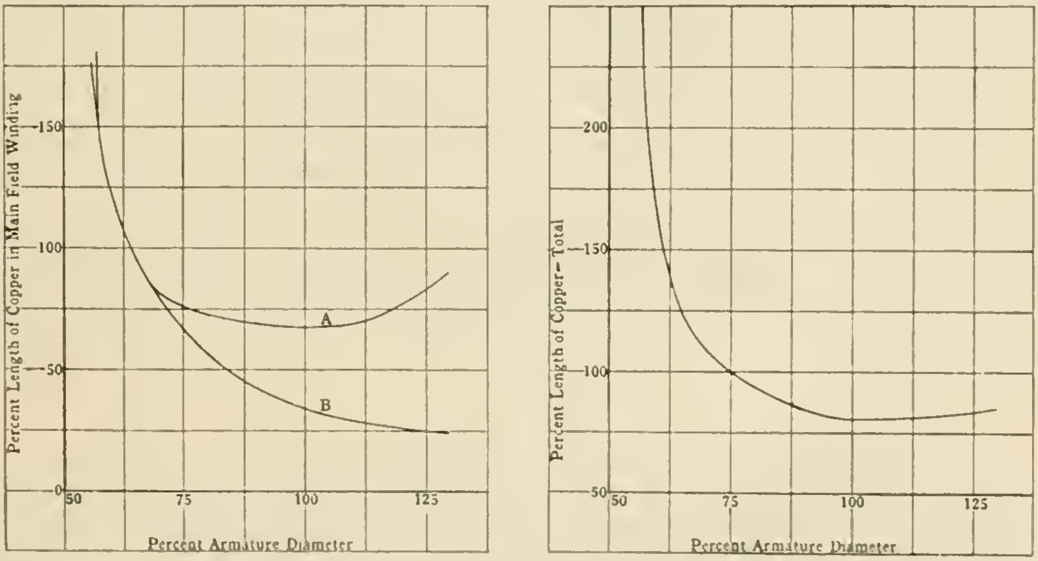


FIG. 1—CURVES SHOWING THE EFFECT OF VARIATION OF ARMATURE DIAMETER

On *A*—Copper within the core; *B*—Copper projecting outside the core; *C*—Resultant of *A* and *B*—total armature copper

Main Field Winding—For a given magnetic strength, a pole of circular shape will give the least possible total length of copper and therefore the least resistance in the main field winding. In railway motors, however, it is not practicable to use circular poles, because of the resulting unfavorable contour of space for field coils between the poles, and, because the laminated structure used cannot be manufactured for circular poles at a reasonable cost. Rectangular poles are therefore much more adaptable in every way. Of rectangular poles, the one of square section will give the shortest length of average turn with the least resistance in the field winding. For example, a 4 by 9 inch pole has the same area as a pole six inches square; whereas the former has a periphery of 26 inches and the latter 24 inches, or eight percent less. This would mean an eight percent smaller resistance and a proportionately smaller loss in the winding. But if a small armature diameter be used the consequent restriction of space between the armature and frame necessitates the use of long and narrow poles which results in greater average length of turn than would be the case with the larger diameter armature. The relation between armature diameter and length of copper in the main field winding is shown in Fig. 2, curve *A*, the magnetic area of the poles being assumed constant throughout. Inspection of the curve shows that a reduction from normal armature diameter of 25 percent, results in about 15 percent increased lenth of copper, with a resultant reduction in motor efficiency.



FIGS. 2 AND 3—CURVES SHOWING THE EFFECT OF VARIATION OF ARMATURE DIAMETER

On the length of copper in the main field winding, *A*, and the commutating field winding, *B*, Fig. 2, and on the length of copper in the total motor circuit, Fig. 3.

Commutating Pole Winding—The effect of armature diameter upon the length of copper is even more noticeable in the commutating field winding. As the armature is reduced and the armature core correspondingly lengthened, the length of the commutating pole will also be increased in about the same proportion. The relation between the average length of turn and the armature diameter is shown in Fig. 2, curve *B*. A reduction of 25 percent of the armature diameter requires about 100 percent more copper in the commutating pole winding.

Total Length of Copper—By adding the ordinates of the curves shown in Figs. 1 and 2, a curve, Fig. 3, is obtained showing how the total length of copper and therefore total motor resistance, is affected by the armature diameter. It will be seen that a reasonable reduction in diameter can be made without a serious reduction in motor efficiency. For instance, a reduction in diameter of five percent can be made from the normal diameter (100 percent) with an increase of only three percent in motor resistance, but a reduction in diameter of 25 percent will result in an increase of resistance of 25 percent. The total motor efficiency will be reduced in the latter case approximately 2 percent. It will be evident, then, that a reasonable reduction in armature diameter can be made without objectionable sacrifice, but that when this is exceeded, serious reduction in motor efficiency will result.

VENTILATION

The problem presented in the ventilating of a railway motor consists in providing a satisfactory means of carrying the heat generated out to the frame where it can be dissipated by radiation. Of the different heat generating parts, the armature is the most difficult to ventilate; and the difficulty increases as the diameter is reduced, a long armature core and the long field coils incident to small diameter of armature offering a relatively high resistance to the flow of the circulating air. Therefore the amount of heat that can be carried to the frame will be somewhat less in this case than in an armature of larger diameter and shorter core and field coils. Furthermore, a small diameter is apt to result in choking the air as it passes through the commutator and armature. In this connection the distance between the commutator V-ring and oil wiper will often prove to be one of the limiting features of the design.

To offset the above handicaps, somewhat heavier sections in copper are necessary with added cost. Or, instead of using larger copper sections, it may be advisable to increase the diameter of the blower. This, however, will require a larger bore in the frame for the pinion end housing, which will mean in turn a larger and more expensive housing and greater expense for machining.

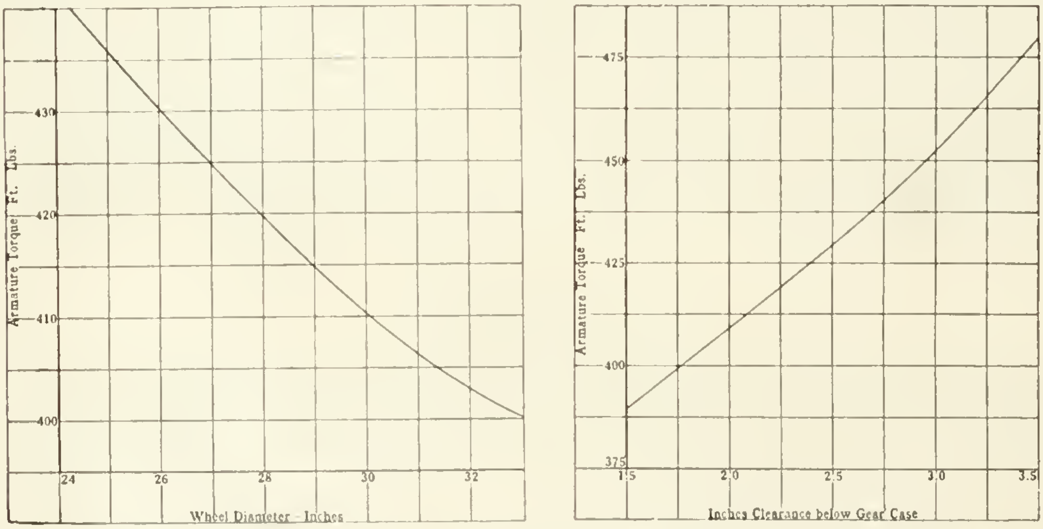
The difficulties encountered in ventilation can in some measure be alleviated by careful consideration of the shape and arrangement of the air passages. For a given area of ventilating duct, the amount of radiating surface will depend upon the shape of the duct. A circular duct will give considerably less radiation surface than one which is long and narrow as, for instance, one of elliptical shape, and is, therefore, proportionately less efficient in its ability to dissipate heat. Further, the sectional areas of the passages should be as uniform as possible, and the transition where necessary from small to larger sectional areas, and vice versa, should be as gradual as possible in order to minimize formation of air pockets, and wasteful eddies. The location of the air passages must be such that there will be no serious blocking of the air by obstacles such as strengthening ribs in commutator, armature end-plates, ring-nuts, etc. The air passages must also be so located and arranged as to render possible their proper alignment in the process of manufacture. The working out of these points is attended with greater difficulty the smaller the armature diameters.

MOTOR WEIGHT

In some respects the smaller diameter of wheels tends toward increased weight and in others toward reduced weight. The respective elements will be balanced, taking into consideration the principles outlined below.

Armature Torque—For a given clearance between the gear case and the top of the rail and for a given amount of power drawn from the line, the mount of torque required in the armature will vary with different wheel sizes. To develop a certain tractive effort at the rail at a given car speed the armature torque required under the above conditions will be greater for a small wheel than for a large wheel under the limiting conditions given below. This fact is illustrated in Fig. 4. In this curve the tractive effort at the rail, the car speed and the clearance below the gear are assumed constant in all cases. Maximum gear reduction is assumed, and the minimum pinion, with the same number of teeth in all cases. These assumptions are in accordance with average city practice and represent a fair basis of comparison. The curve shows that the torque which must be developed in the armature for a 24-inch wheel is about ten percent greater than that required for a 33-inch wheel. To obtain this greater torque will require a slower armature speed resulting in corresponding greater motor weight, and increased cost in manufacture.

Clearance Below Gear Case—The influence of the wheel size, with fixed clearance below the gear case, upon the weight of motors has been considered above. Sometimes, however, conditions are such that the wheel diameter is fixed. In this case, to overcome the disadvantage of small wheels above pointed out, it may be necessary to sacrifice a certain amount of clearance beneath the gear case, thereby obtaining a more favorable gear reduction by the use of a larger gear. The influence upon motor weight of varying the clearance below the gear case is shown in Fig. 5, in which the assumptions made under the heading "Armature Torque" apply, with the exception that the wheel size is fixed at 26 inches and the clearance below the gear case is varied. As the clearance beneath the gear case is increased, the number of teeth in the gear must be correspondingly decreased, resulting in a smaller gear reduction. Thus the torque developed by the armature is transmitted to the rail at a mechanical disadvantage. For instance, with a 26-inch wheel, a three-inch clearance requires ten percent greater torque at the armature shaft than a two-inch clearance. This requires a correspondingly slower speed armature and greater weight.



FIGS. 4 AND 5—CURVES SHOWING THE EFFECT OF VARIATION OF WHEEL DIAMETER AND ASSUMED CLEARANCE ON THE ARMATURE TORQUE REQUIRED FOR A GIVEN TRACTIVE EFFORT

Length of Magnetic Circuit—The above tendencies toward increased weight are in a measure offset by the fact that the weight of the magnetic parts of a motor is inherently less for a small armature diameter. The sectional areas of the magnetic parts do not vary materially for different armature diameters. Therefore, the weight of the magnetic parts will be roughly proportional to the diameter of motor. In this connection the tendency toward lighter motor weight involved in the use of small armature diameters is most pronounced in the case of slow speed motors, owing to the fact that the weight of the magnetic parts in slow-speed motors constitutes, in general, a larger proportion of the total motor weight than in higher speed motors.

The Sheet Steel Gear Case possesses advantages in connection with motor weight which have led to its extensive use in low-floor cars where the many limitations imposed require that advantage be taken of every possible gain. The advantages of sheet steel as compared with that of malleable iron are two-fold. First, the weight of the former is less by 50 to 60 percent; it can be manufactured very close to drawing dimensions, and clearances can be figured very closely; whereas, on the other hand, the thickness of the walls of the malleable iron case, being a casting, may vary one-eighth to one-quarter inch from specified drawing dimensions. Therefore, to insure a reasonable clearance between gear and gear case, it is necessary to figure on a somewhat smaller outside diameter of gear for the malleable iron case than would be possible with the sheet steel case. This means smaller gear reduction and for a given tractive effort a somewhat slower speed and heavier motor. On the other hand, the sheet steel gear case is 25 to 35 percent more expensive to build than the malleable iron case, which imposes a limitation upon the general use of this style of case.

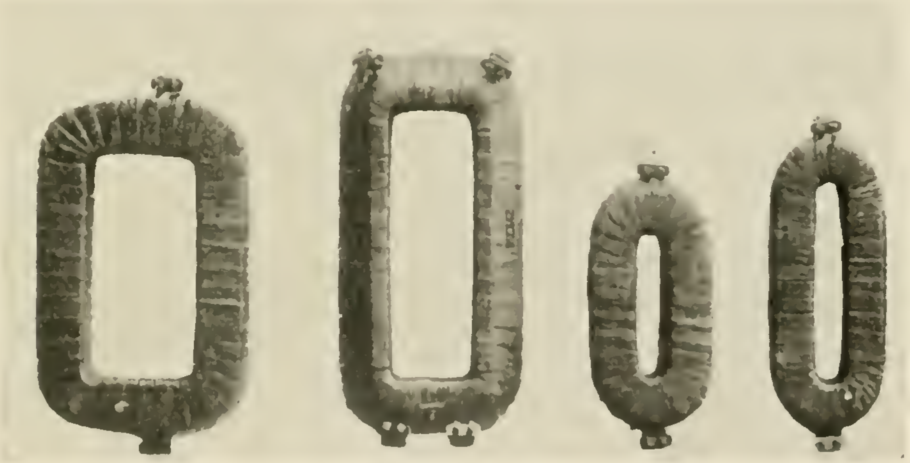


FIG. 6 COMPARISON OF MAIN AND COMMUTATING FIELD COILS FOR STANDARD AND LOW FLOOR CAR MOTORS

NET RESULT IN MOTOR WEIGHT

The net result of the above opposing tendencies in motor weight will depend upon the particular case considered. For the average city service which, in general, requires motors ranging from 40 to 50 horse-power, a motor for 26-inch wheels will be 5 to 10 percent heavier than one for a 33-inch wheel. In this it is assumed that the comparison is made under the conditions of gear case clearance, gear reduction, etc., mentioned under heading "Armature Torque."

Where the character of street paving and other operating conditions will permit the use of a sheet steel gear case and also of a smaller clearance below the gear case than is ordinarily considered for large wheels, excessive motor weight can be avoided, although the cost of building the motor will still be greater by 10 to 20 percent, on account of the extra cost of copper and extra cost of machining and assembling involved.

GENERAL

No attempt has been made to give a complete analysis of the relation of armature diameters to cost and weight of motor. Rather, it has been the aim of the writer to point out for the benefit of operating men, some of the principal features met with in the design of railway motors, which have a vital bearing upon the entire question of motor application. It is believed that some of the difficulties which have been met in the design of motors for low-floor cars are directly traceable to the extreme quickness of development which has characterized this comparatively new line of railway work. Naturally, under these circumstances there has not been the time nor opportunity for a free interchange of ideas and comments between the designers of motors and the designers of the car trucks and body. In some cases this has led to the arbitrary fixing of certain dimensions and features of the car layout, such as clearance over and under motor frame, clearance beneath gear case, position of brake-rods, underframing, etc., which have been seriously detrimental to the design of electrical equipment, and in all probability to the entire layout of car. Inasmuch as the successful operation and maintenance of electric railways depends most vitally upon the design, construction, and operation of the electrical equipment, too much stress cannot be laid upon the necessity for close coöperation between operating and manufacturing companies, as only by this course can the best results be obtained.

THE DYNAMOTOR-COMPRESSOR

RALPH E. FERRIS

THE dynamotor is in reality a direct-current voltage transformer, and the voltage transformer for alternating current offers a very good analogy upon which to base an explanation. Briefly the dynamotor consists of two separate and distinct armature windings on the same core, each connected to its individual commutator. The two windings have a common field and therefore the generated e.m.f. per turn is the same for each winding at any given field excitation; or the voltage at each commutator is equal to some factor times the number of turns in series in the winding. If, for example, one winding had twice as many turns in series as the other, and 1 200 volts were to be applied to the winding with the larger number of turns, the voltage at the other commutator would be 600. This is similar to the condition obtaining in an alternating-current voltage transformer, as illustrated diagramatically in Figs. 1 and 2. In Fig. 1, A and A_1 are two armature windings on the same core with series fields F and F_1 and shunt fields S, giving a resultant field common to both windings. Armature winding A has 1 200 turns and winding A_1 has 600 turns. If with this connection 1 200 volts be applied to A, current at 600 volts, less the I R drop, could be drawn from A_1. Fig. 2 is a diagram of connections for a double winding alternating-current voltage transformer, showing the relation electrically between the dynamotor of Fig. 1 and the ordinary transformer.

A second method of transforming from 1 200 to 600 volts direct current is to use the same number of turns in each winding and connect the two in series externally. Current at 600 volts may then be obtained by tapping off at the middle point between the two windings. An auto-transformer is practically an analogy to the dynamotor connected according to this second method, and the points in favor of an auto-transformer over a double winding transformer also apply to the second method of connecting the dynamotor. This analogy is illustrated diagramatically in Figs. 3 and 4. The transformer illustrated in Fig. 4 has only one winding, a certain portion of which is used for both the high tension and low tension current. Also the dynamotor illustrated in Fig. 3 has only one winding, composed of two parts, one part of which is used for both 600 and 1200 volts. The number of turns used in the transformer shown in Fig. 4 is the same as if it were used exclusively for the high tensoin winding and a separate additional coil were provided for the low tension winding, as shown in Fig. 2. Exactly the same conditions exist as regards the number of turns on the dynamotor shown in Fig. 3 compared to the one shown in Fig. 1. In other words, the dynamotor and transformer shown in Figs. 1 and 2 require 50 percent more turns than the dynamotor and transformer shown in Figs. 3 and 4 respectively.

The copper required for the second method of connection for both dynamotor and transformer is less, as will be readily understood from the following:—Suppose, for example, that 12 amperes are to be delivered at 600 volts, or 7 200 watts. This would mean, assuming no losses, that six amperes must be drawn from the 1 200 volt line for both dynamotor and transformer, no matter what the method of connection. Therefore, the copper in the 1 200 turn armature of Fig. 1 and the 1 200 turn primary of Fig. 2 must be sufficient to carry six amperes and, in addition, the copper in the 600 turn armature and 600 turn secondary of the dynamotor and transformer respectively, must be sufficient to carry 12 amperes. However, the second method of connecting does away with the winding required to carry 12 amperes entirely, the current traversing the circuits as follows:—Six amperes from *a* to *b*, Figs. 3 and 4, and six amperes from *c* to *b*, making a total of 12 amperes flowing out at point *b*.

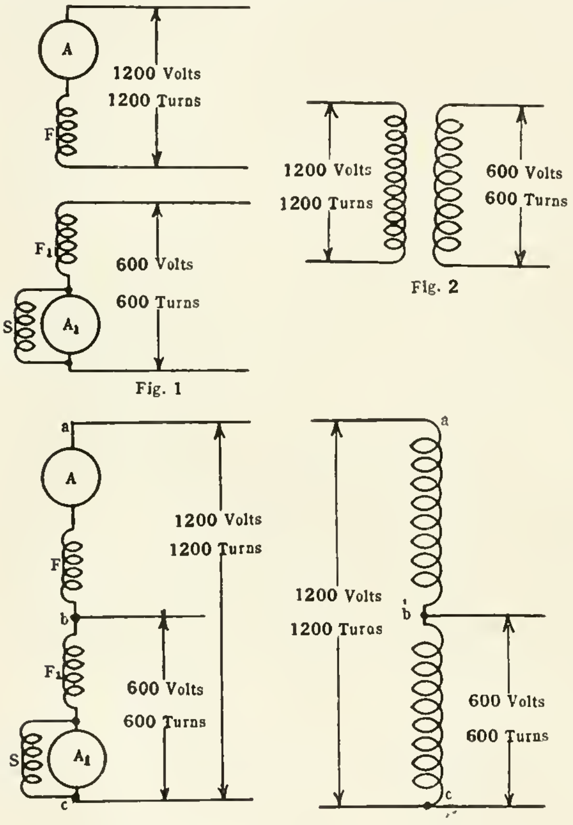


Fig. 1 Fig. 2 Fig. 3 Fig. 4

FIGS. 1 TO 4—DIAGRAMS SHOWING ANALOGY BETWEEN THE DYNAMOTOR AND THE ALTERNATING-CURRENT TRANSFORMER

With the introduction of high voltage direct current for railway work, where the locomotive or car is required to operate either on 1 200 or 600 volts, the dynamotor presented itself as a means of generating 600 volts direct current, while on the 1 200 volt section, for lights, control, compressor and blower motors.

The dynamotor-compressor combines the dynamotor, the compressor motor, and blower motor all in one, thus materially reducing the weight and also the space required for the outfit. This is accomplished by using the dynamotor as a motor and driving the compressor thereby through a set of gears and a multiple-disc clutch. If a blower is required on the car or locomotive, an extended shaft is used and the blower mounted directly thereon.

NO LOAD

As indicated in Fig. 3, the series field is divided into two parts, *F* and F_1. Each of these parts is divided into four coils, one on each pole. Under no load conditions, the dynamotor-compressor is excited almost entirely by the shunt field. Say, for example, that the series turns for each section are 400, or 100 turns per pole, giving 200 turns per pole for both sections. If when running under no load the dynamotor takes one ampere to overcome friction and windage, there will be 200 ampere turns per pole from the series field. Assuming 1 400 ampere-turns from the shunt field, the total ampere-turns per pole would be 1 000. Under this excitation, the dynamotor would run at a certain speed.

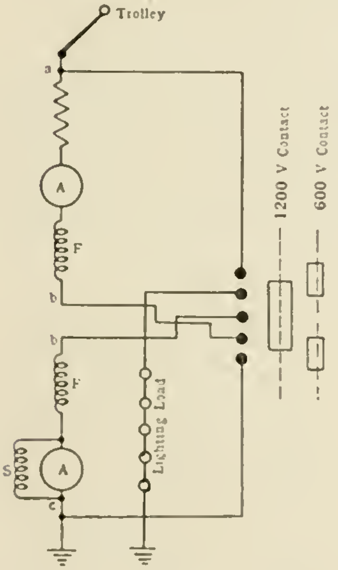


FIG. 5—DIAGRAM OF CONNECTIONS

Showing method of changing over the dynamotor circuit with change in line voltage.

LIGHTING LOAD ONLY

Assume any lighting load from zero up to maximum, say, for the purpose of illustration, 12 amperes at 600 volts, or 7 200 watts. In addition to the 7 200 watts lighting load, 1 200 watts are required to overcome friction and windage, making a total of 8 400 watts to be delivered by the power supply. The current drawn from the 1 200 volt line would be, therefore, (8 400 ÷ 1 200 =) seven amperes. This gives in the high voltage armature and field circuit *a* to *b*, Fig. 3, a current of seven amperes. As 12 amperes are to be drawn from the circuit at *b*, it is very evident that the remaining five amperes must be supplied by the low voltage armature winding acting as a generator. There will be, therefore, five amperes in the circuit from *c* to *b* flowing in an opposite direction to that in circuit *a* to *b*. The ampere-turns delivered by the series field *F* in this case would be 700, and in F_1 would be 500 in the opposite direction, so that the total ampere-turns would equal 200, which is the same as under the no load condition. The speed, therefore, remains approximately the same as under no load. In other words, the amount of current drawn from the circuit at *b* does not materially affect the speed of the dynamotor.

COMPRESSOR ONLY

When the dynamotor is running the compressor alone, it is again working as a straight motor, and the current flows from *a* to *c*, Fig. 3. If, for example, the compressor requires 6.5 horse-power, including friction and windage, or approximately 4 800 watts, the current in circuit *a* to *c* would be four amperes, and the ampere-turns per pole delivered by the series field would be (4 × 200 =) 800. The shunt ampere-turns remain constant, so the speed with compressor only would be lower than under the no load or lighting load condition.

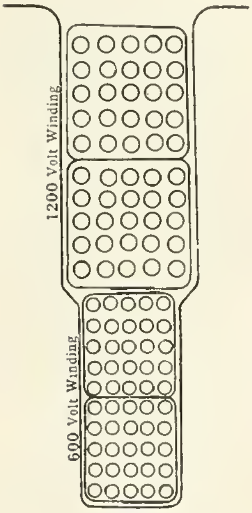


FIG. 6—CROSS-SECTION OF ARMATURE SLOT

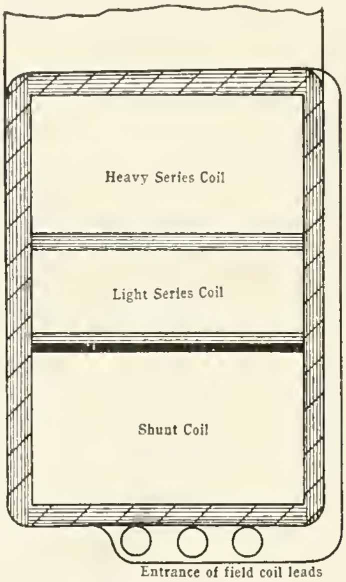


FIG. 7—CROSS-SECTION OF FIELD COIL

Showing relative positions of the three windings.

COMPRESSOR AND LIGHTING LOAD

Obviously all the power delivered by the dynamotor-compressor outfit, both mechanical and electrical, must be derived primarily from the power supply. We have, therefore, 7 200 watts lighting load and 4 800 watts for the compressor, including friction and windage, making a total of 12 000 watts or ten amperes to be supplied by the 1 200 volt trolley. This would give then ten amperes in the circuit from *a* to *b*. The remaining two amperes to make up the 12 amperes lighting load would be supplied by the low voltage armature acting as a generator, the current flowing from *c* to *b*. The ampere-turns per pole delivered by the series field would be 800, or the same as with the compressor only. It is evident, then, that the dynamotor-compressor outfit has only two speeds, one under the no load condition and the other when operating the compressor. The lighting load has no effect on the speed in either case.

With the compressor on and with a certain value of current drawn from the circuit at *b* the low voltage armature and field circuit *b* to *c*, would be running idle. For example, using the same value of 4 800 watts for compressor, including friction and windage, and eight amperes, or 4 800 watts lighting load, giving a total of 9 600 watts to be supplied by the line, a current of (9 600 ÷ 1 200 =) eight amperes would flow from *a* to *b* and out through the line tapped at *b*. In other words, the armature on the low voltage side would be floating on the line, acting either as a motor, a generator or running idle, depending on the conditions.

OPERATION ON 600 VOLTS

When the locomotive or car passes from the 1 200 volt section to the 600 volt section, a change-over switch is operated, the connections being as shown in Fig. 5. The compressor load, including friction and windage, will still be 4 800 watts, but on 600 volts the current drawn from the line will be (4 800 ÷ 600 =) eight amperes. It will be noted from Fig. 5 that only half the series field is in circuit, so the ampere-turns per pole delivered by the series field will be (100 × 8 =) 800 ampere-turns, or the same as when operating the compressor on 1 200 volts. The shunt field is excited from the low voltage armature and will add its approximately constant ampere turns to the series field as before. As the 600 volts is impressed across one armature and series field only, the speed of the dynamotor when operating the compressor will be approximately the same as on 1 200 volts. The lighting load, as indicated in Fig. 5, is supplied direct from the 600 volt line.

UNEQUAL VOLTAGE OPERATION

The preceding examples and discussion have been based on 1 200-600 volt operation, merely to simplify the explanation. It is perfectly possible to transform from any voltage, limited only by the commutation, to some lower voltage which may be one-half primary voltage, less than one-half or more than one-half. For example, dynamotor-compressors have been built in which the transformation is from 1 500 volts to 600 volts. Following the same method of explanation as used for the 1 200-600 volt dynamotor, if armature *A*, Fig. 3, had 900 turns, and armature A_1, 600 turns, then if 1 500 volts were applied to the two armatures in series current at 600 volts could be drawn from the circuit at *b*. In this case the voltage across armature *A*, Fig. 3, is 900 volts and the voltage across A_1 600 volts.

In order to obtain two speed conditions only, as was the case with the 1 200-600 volt example, the fields F and F_1, Fig. 3, must be unequal, for, with the same load as before, namely 12 000 watts for both mechanical and electrical load and the same design of series field, eight amperes flow from a to b, and four amperes flow from c to b, making up the total of 12 amperes at 600 volts for the lighting load. Under this condition the excitation period by the series field would be 400 ampere-turns per pole. If, however, the mechanical load of 4 800 watts only is being carried, then the current in the circuit from a to c is $(4\,800 \div 1\,500 =)$ 3.2 amperes and the ampere-turns on the series field per pole would be equal to 640. In order, therefore, to obtain the same speed with the lighting load on as off, the field sections F and F_1 should have the same ratio as the voltages on the two armatures. In the case under consideration the ratio would be 900 to 600. Using this ratio, field section F would have 120 turns per pole and F_1, 80 turns per pole. With this arrangement, the ampere-turns delivered by the series field per pole with lighting load on, is $((120 \times 8) - (80 \times 4) =)$ 640, and with lighting load off is $(3.2(120 + 80) =)$ 640, thus giving approximately the same speed with or without lighting load.

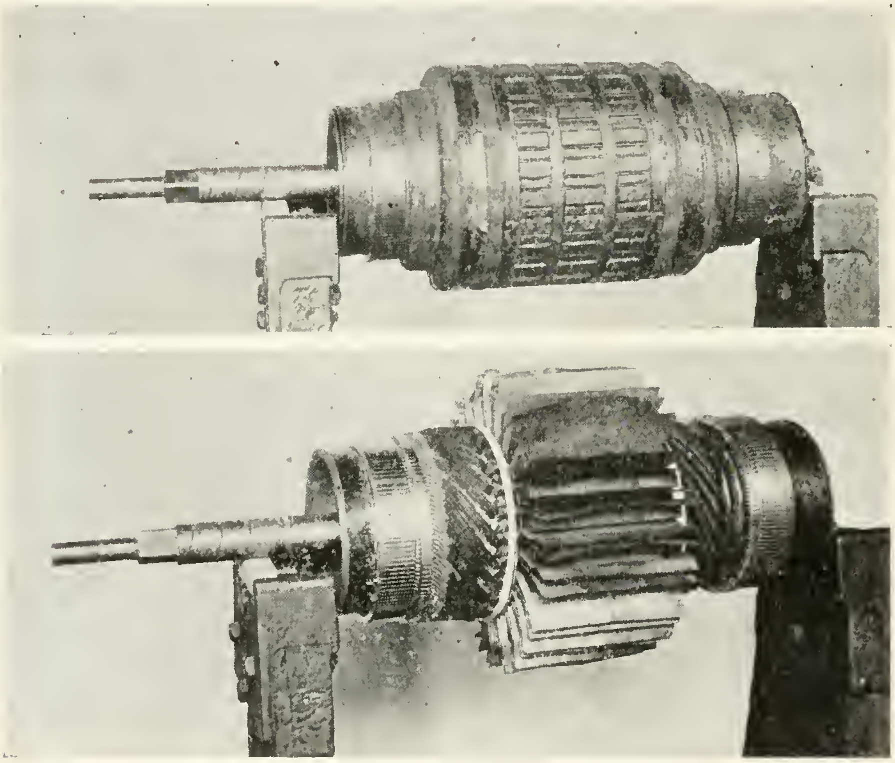


FIG. 8—DYNAMOTOR ARMATURE COMPLETE AND WITH LOWER WINDING ONLY IN PLACE.
Extended shaft for use with blower.

ROTOR

It is evident from the discussion under the different conditions of operation that if any current at all is drawn from circuit at *b* (Fig. 3) on 1 200 volts, the square root of the mean square of the current in circuit *c* to *b* will be less than in circuit *a* to *b*. This being the case, the winding in the low voltage side is placed in the bottom of the slot, which is of reduced cross-section, permitted by the smaller* size of wire, and is completely connected to its commutator before the coils for the high voltage side are wound in place. The armature coils are standard machine wound and insulated for full voltage to ground with mica wrappers. A cross-section of an armature slot with coils in place is shown in Fig. 6. The permissible reduction in cross-section of slot at the bottom greatly facilitates the design of the dynamotor, as the average cross-section of tooth is much larger than would be the case if the slot were the same width for the entire depth.

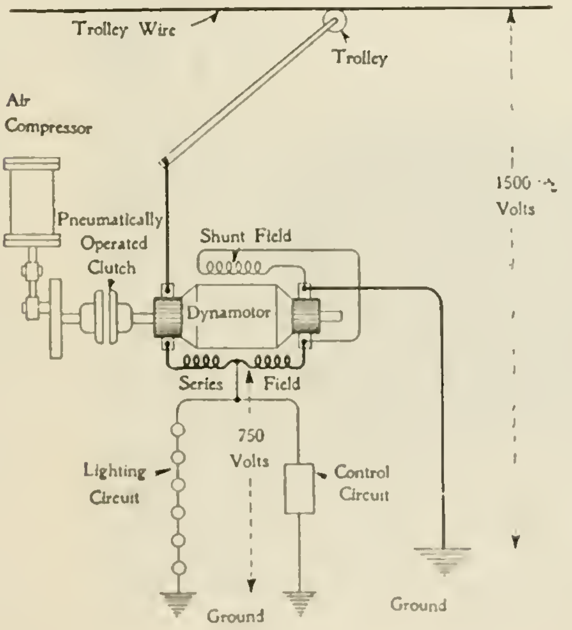


FIG. 9—ELEMENTARY DIAGRAM OF DYNAMOTOR CIRCUIT

The commutators on the 1 500-750 volt or 1 200-600 volt dynamotors are exactly the same on both low and high voltage side except for the extension of neck, which is much longer on the high voltage than on the low voltage side. The commutators on the 1 500-600 volt dynamotors have an additional difference in that the commutator for the high voltage side has a greater number of bars than the one for the low voltage side. An armature with lower winding in place, and a completed armature with shaft extension for use with blower, are shown in Fig. 8.

STATOR

The dynamotors are generally compound wound, but in some cases straight series windings have been used. The field winding is divided up into three separate and distinct parts. Referring to Fig. 3, the portion of field marked *F* is divided up into four coils, one for each pole, and carries the same current as does the high voltage armature. The portion of field marked F_1 is also divided up into four coils, one on each pole, and carries the same current as does the low voltage armature. The shunt field is excited from the low voltage armature and is also divided up into four coils, one on each side. This means, therefore, there are three coils per pole. These coils are, however, all wound on one shell, being suitably insulated from each other internally so that the winding as a whole presents the appearance of only one coil per pole. In the case of a straight series dynamotor, sometimes used where the outfit is equipped with a blower, there are, of course, only two coils per pole. A cross-section of a compound-wound field coil is shown in Fig. 7.

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*In the case of unequal voltage armatures the wire in the low voltage armature may be approximately the same cross-section as that in the high voltage armature, but the number of turns would, of course, be less, thus in either case permitting the smaller slot.

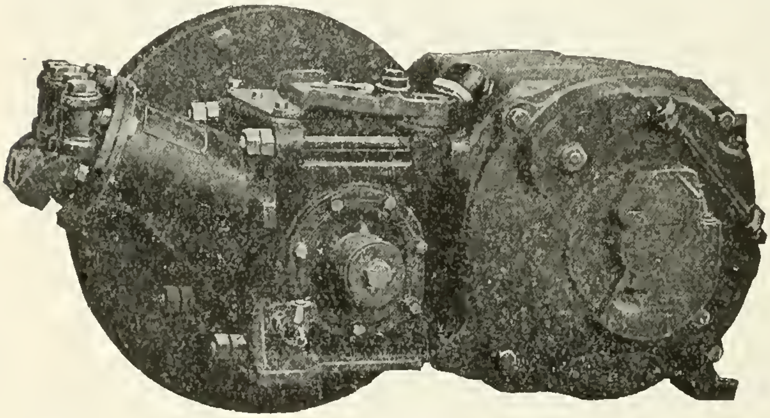
FIG. 10—DYNAMOTOR-COMPRESSOR OUTFIT COMPLETE

The magnet frames of the dynamotor-compressors are made of soft steel, cast in a single piece. At each end is a large bored opening through which the armature, pole pieces and field coils may be removed. The openings are closed by solid housings carrying the shaft bearings and oil wells. The main pole pieces are built up of sheet steel riveted to heavy end plates, and are bolted to finished seats on the frame, thus making a good magnetic fit.

CLUTCH

The dynamotor runs continuously and the compressor is automatically cut in or out, as required, by means of a multiple-disc clutch designed for this purpose. The clutch consists of two sets of steel discs. While driving the compressor, the two sets of discs are pressed together by a spring of suitable strength. When the air pressure in the receiving tank has reached a predetermined value, air at this pressure is admitted to a piston cylinder which compresses the spring and permits the discs to run free. When the tank pressure reaches a predetermined minimum value, the air in the cylinder is automatically released by a governor, the spring closes the clutch and the compressor starts pumping again.

COMPRESSOR

The compressors used are of a standard type, using the splash system of lubrication. A small amount of oil is splashed through from the crank case into the gear case, and the gear in turn carries the oil up, throwing it over and around the clutch, and also into the dynamotor bearing at the clutch end. The gears and clutch are therefore running in a bath of oil, the excess being returned to the crank case by means of an overflow return channel. An elementary diagram of the dynamotor-compressor is shown in Fig. 9.

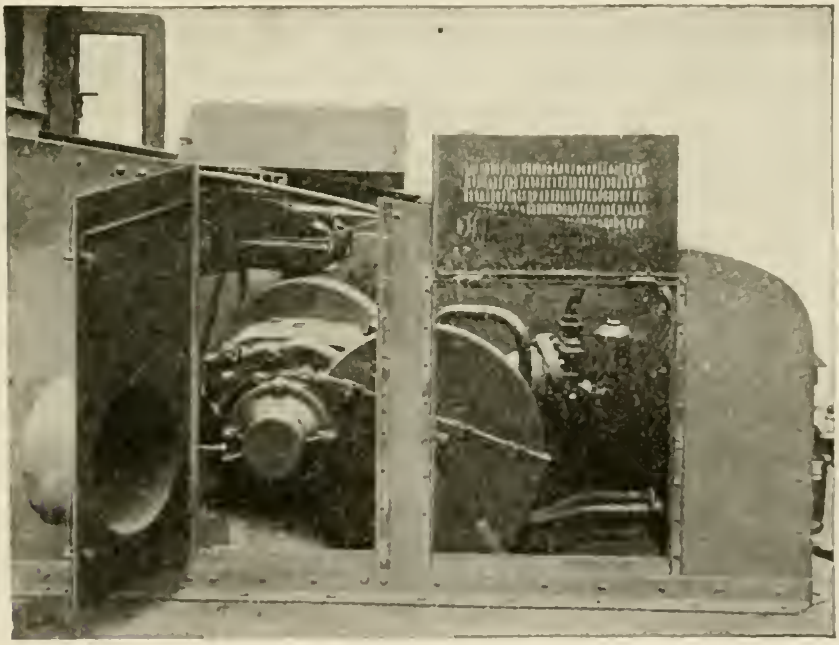

FIG. 11—DYNAMOTOR-COMPRESSOR MOUNTED IN 1 500 VOLT ELECTRIC LOCOMOTIVE

OPERATING CHARACTERISTICS

The dynamotor is connected direct to the trolley through suitable cut-out and change-over switches. This being the case, any interruption in the trolley circuit, such as trolley flying off, passing over cross-overs, etc., would open the dynamotor circuit. The dynamotor must, therefore, be capable of withstanding full voltage applied suddenly at any and all times.

The dynamotor compressor performs the duties for which two or three machines were formerly required, the machines it replaces being a dynamotor, a compressor motor and a blower motor. This combination of two or three machines in one gives a saving in weight of equipment of approximately 900 lbs.

NOTES ON THE MANUFACTURE OF ELECTRIC RAILWAY APPARATUS*

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Westinghouse Electric & Mfg. Company

TO THE UNINITIATED, a railway motor has usually seemed a rather rough piece of apparatus put together by semi-skilled mechanics later to be turned over to the tender mercies of the car barn man and operated with a minimum of attention. There is, however, a growing appreciation of the requirements to be met and of the necessity of having all parts of the railway equipment strong and serviceable, mechanically as well as electrically. The very severe vibration and strain to which mechanism mounted upon the trucks and frame of a car or locomotive is subjected demands accurate fitting of the parts and the use of none but the best materials.

The first of the prime factors facing a manufacturer is the question of tools—to what extent standard machine tools can be utilized and what special facilities must be provided. To manufacture economically in this day of scientific study, it is obvious that the plant must be furnished with tools, jigs, fixtures, etc., to as great an extent as the business will warrant, and it is to the determination of this latter that the works management devotes no little time and study. There is no uncertainty as to the provision of jigs, etc., which will insure accuracy and interchangeability of parts, but the question of special machine tools is not so easily solved. A railway motor would seem, at first thought, to be comparatively simple and unchanging in so far as machining operations are concerned; nevertheless, it has been found that the types and designs vary to such an extent as to preclude machine tools designed for any particular motor. This has resulted in the development of machine tools especially adapted to motor work but applicable to all kinds of motors. Among these may be mentioned milling machines and cutters for milling frames, axle cap seats, etc.; boring mills with four spindles whereby armature housing fits and axle seats are bored at one setting; floor boring mills for boring pole seats; hydraulic presses for tamping down laminations in the process of building armature cores; and soldering pots for soldering leads in commutators.

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*In an article appearing in the JOURNAL for October, 1911,, Mr. C. B. Auel outlined some of the essential features entering into the manufacture of a railway motor and this article may be considered as supplementing Mr. Auel's description.

In carrying out machining operations upon parts that are expected to be alike and later fit into their respective places in the completely assembled unit, a high degree of accuracy is necessary, yet, since there is practically no such thing as exact dimensions, a very well defined system of allowances or tolerances must be outlined. For every given dimension a certain variation therefrom is allowable and no more. It becomes the duty of the inspectors to enforce these rules and it has been found entirely practicable to lay out such a system.

Some of the points calling for consideration in the manufacture of railway apparatus may be mentioned as follows:—

RAILWAY MOTOR FRAMES

The production of railway motor frames requires care at the very outset, in the pattern shop. As castings are turned out in large quantities it is necessary that the patterns be accurate and very strongly made. The moulding and core making needs close attention. Many steel foundries doing general business but without experience in the work find it impossible for some time to turn out acceptable castings. The walls of the castings must be true to pattern, not over thick in spots, and free from blow holes. A porous casting is often rejected when the holes are not visible but the motor is "off speed" due to weakened field. The electric welder has come to the rescue of the foundry in recent years and has reclaimed many castings that otherwise would be scrapped.

After the casting has been received, it is necessary that it be laid out carefully for the location of center of shaft and the angle and center of axle. If these are not right the motor is likely to be out of balance—that is, the magnetic sections will not be uniform and some parts may not true up.

It is usual to bore the pole seats 1/64 inch out of center to allow for wear of bearings, and to do this it is necessary that the boring bar and bearings of the floor boring mill be in good adjustment. The axle caps and armature bearing housings must fit close and, above all, the axle caps and housing bolts must be true and tight as to thread. It has been found impossible to secure the necessary accuracy of thread on these bolts in a bolt machine and as a consequence all axle cap bolts and all housing bolts are turned and threaded in a lathe.

ARMATURE

The shafts are made of carefully tested axle steel or heat treated forgings and, after being centered and rough turned, are put in a special spotting lathe, in which several tools are operated at once. Adjacent to every shoulder the spotting tool also forms the very necessary fillet and provides a clearance for the grinding wheel. After spotting the shafts are ground down to drawing dimensions.

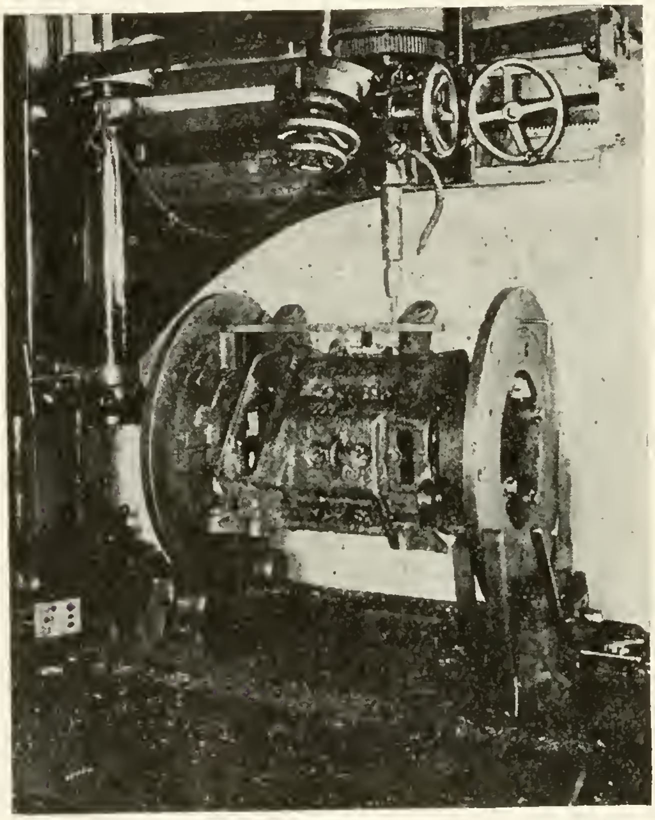


FIG. 1—SPECIAL DRILLING JIG USED IN THE ASSEMBLING OF RAILWAY MOTOR FRAMES

The spiders are usually of malleable iron and both spider and shaft, after being turned down, are ground down to size and finish; allowance for press fit is made on the shaft and about 0.002 inch is allowed on the outside of the spider to insure tight fitting laminations. The peripheral speed of the grinding wheels is between 5 000 and 6 000 feet per minute and of the shaft and spider 50 and 60 feet per minute: if the latter speed is much exceeded a chatter is set up where the grinding wheel passes the keyway in the shaft or one of the open spaces of the spider. The quality of finish on shafts and spiders is very largely dependent upon the cutting compound used. Many mixtures have been tried but the cheapest compound that would give good finish has been found to be 50 gallons of water, 2 gallons of lard oil and 12 lbs. of soda.

The pinion seat is turned up to a taper of 1.219 or 1.125 inches per foot. The small pinions are heated in boiling water for at least one half hour and then driven upon the shaft with a sledge. Pinions transmitting much over 100 horse-power are heated to 150 degrees C. and driven upon the shaft. With the above tapers and method of applying pinions, fits equal to pressures of 20 to 25 tons are obtained with the smaller pinion and 70 to 80 tons with the larger.

Laminations are punched from specially made mill annealed iron, 0.017 to 0.028 inch thick. The iron sheets are of the proper width to correspond to the diameter of the armature and are fed under the punch with the aid of a unique pneumatic lifter which renders it unecessary for the operator to put his fingers under the press. Very accurate compound dies made of high-speed steel are used. After being punched the laminations are run through an enameling machine and are ready for building upon the spider.

Commutators are remarkably substantial pieces of mechanism composed as they are of many parts held together with insulation between. This is due to the machining of all parts very accurately to gauge and to well worked out relationships between the various angles of the different parts. The bushings of some commutators, where no ventilating openings are needed, are pressed or forged out under a 1 000 ton press.

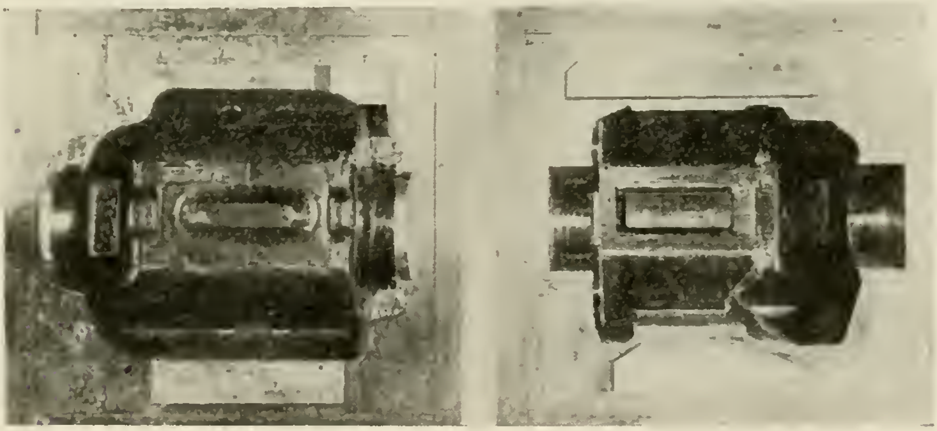


FIG. 2—PATTERN FOR RAILWAY MOTOR FRAME

Showing upper half of cope and drag.

Winding—The coils with which railway motors are wound may be classified in three groups, viz:—

1—Wire coils wound on mould.
2—Wire coils wound on shuttle and pulled or formed.
3—Strap coils wound on shuttle and formed.

In general the insulating and treating of the different types of coils is similar. After coils are formed, shellaced paper strips (0.010 in.) are inserted between single coils on straight parts. The coils are then heated and pressed (being allowed to cool in the press) to make the part which fits into the slots straight and to exact size. Later the coils receive the various wrappings, dippings and bakings as may be specified for the service.

Probably the most unique operation in the process of applying the winding to the armature core is the method of soldering the leads into the commutator bars. This is done in a special pot the central portion of which consists of a shallow circular trough, the outer edge being higher than the inner. The armature, with commutator, is picked up by the pinion end and let down into the center opening, the necks of the bars resting on the inner edge of the trough and in effect increasing the height of this edge. At either side of the circular trough are reservoirs filled with molten solder; by lowering plungers into these reservoirs the solder is caused to overflow into the trough to a depth equal to that of the height of the necks of the commutator bars into which the wires are to be soldered. The commutator is allowed to remain in this position for three to five minutes during which time the molten metal heats up the parts to be soldered and fills up all the interstices between the leads and sides of slots in the commutator bars, a suitable flux being, of course, applied to the commutator connections before putting it in the pot.

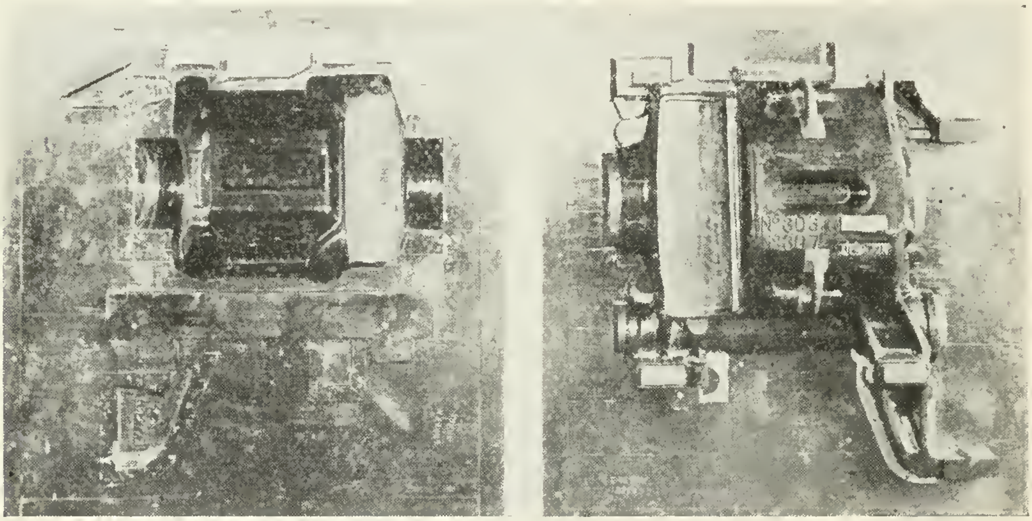


FIG. 3—PATTERN FOR RAILWAY MOTOR FRAME
Showing lower half of drag and cope.

The plungers are then raised and the solder flows back into the reservoirs and the armature is lifted out. The temperature of the molten solder in the reservoirs is held at 825-850 degrees F.

by an automatic regulator. It is often questioned as to whether this high temperature does not injure the insulation on the leads. Such is not the case, as the copper, even in the commutator necks, reaches a temperature only about half that of the solder and the whole cools off very rapidly after being removed from the pot. For use in a pot of this kind, solder composed of 85 parts tin and 15 of lead is best suited. Pure tin might be desirable but it attacks the copper to too great an extent.

For soldering the rear connections of armatures wound with two piece coils, a special gas heated iron is used which gives not only quicker but better results than a hand iron. The armature is placed in a lathe which is fitted with gearing enabling the armature to be turned to bring the connectors slowly and uniformly under the influence of the iron; the ends of the connectors presented to the soldering device having been previously faced off in a lathe.

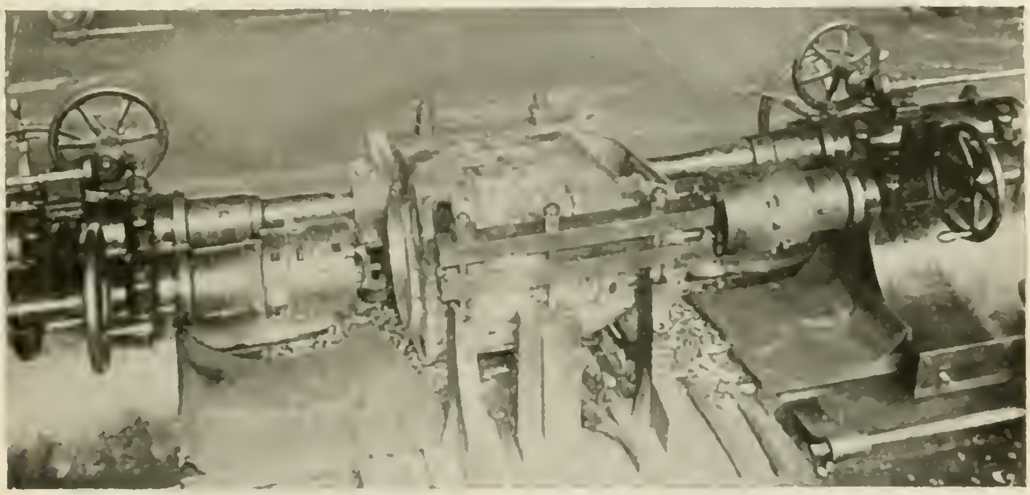


FIG. 4—FOUR SPINDLE BORING MILL

For simultaneous boring of armature housing fits and axle seats.

BEARINGS

Bronze bearings both for armature and axle seem to be growing in favor, although the iron shell, babbitted, will usually give equally good results, providing the babbitt is properly applied. Most of the difficulty experienced with babbitted bearings is due to the babbitt not being applied properly and at the correct temperature. Bearings and mandrels must, in addition to being clean, be so arranged as to preclude the formation of air pockets. Further, every precaution must be taken to keep the babbitt at the temperature best suited for the alloy used. Very extraordinary variations are produced in the mechanical properties of many babbitt metals by differences in the heat at time of pouring. A mandrel or broach driven through a babbitted bearing increases the wearing qualities by adding to the density of the material at and near the surface.

SPOT WELDING

A recent development that has been applied to some extent in the manufacture of electric railway apparatus is spot welding. The device for performing this operation consists of a transformer supplying electric current at low voltage but in considerable quantity to two terminals which constitute the jaws of a press between which the parts to be welded are placed and subjected to pressure at the point of the passage of the current.

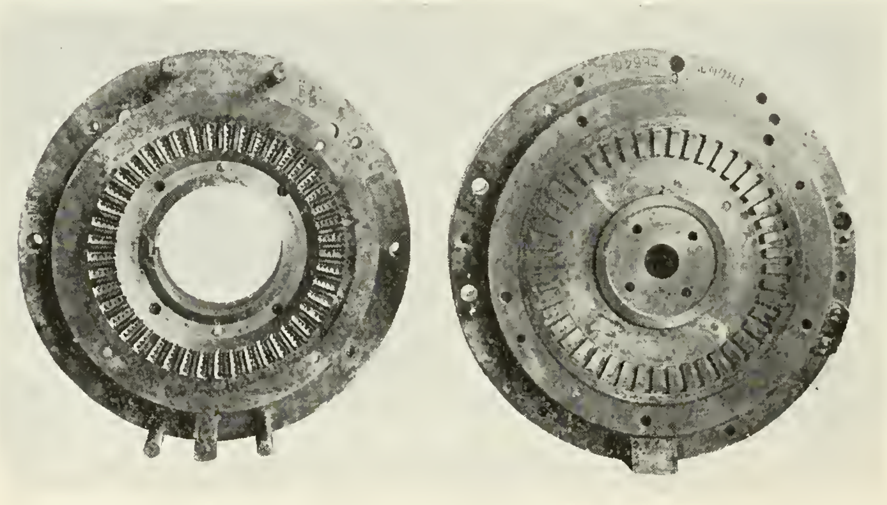


FIG. 5—COMPOUND DIE USED IN THE MANUFACTURE OF RAILWAY MOTOR PUNCHINGS

The spot weld takes the place of a rivet or bolt and, when properly made, the parts are held even more firmly than by rivets, and material economy in manufacture is effected. The weld is used, in the making of pressed steel gear cases, to fasten the supporting plates, etc., to the pressed blank, for welding together several armature punchings to act as finger plates, for welding springs placed under field coils, attaching parts to switch group covers and for many other purposes.

MOTORS FOR LOCOMOTIVES

The building of larger motors for locomotive work presents some characteristic features entirely different from the ordinary railway motors. For instance the large alternating-current motors used on the New Haven Railroad passenger locomotives consist of an outer steel frame or shell into which the laminated magnetic circuit of the field is built. The armature is a steel spider carrying the commutator and laminations assembled thereon. This motor is too large for the punchings composing the laminated sections to be made in one piece; they are, therefore, punched in segments. These segments have dovetail shaped projections which fit into similar shaped slots in the ribs of frame and spider. The machining of these slots requires very accurate work as otherwise the laminations will be loose or will "buckle." Special milling cutters are used, operated by a special milling machine which is mounted upon a dividing table, the whole oufit being set down inside the field frame. For the reason just mentioned the peripheral spacing of the dovetail slots must be exact, as also the distance of the cutter from the center. The milling of the spider is accomplished in a manner similar to that of the frame except that the spider is mounted upon the dividing table and rotated in front of the milling machine.

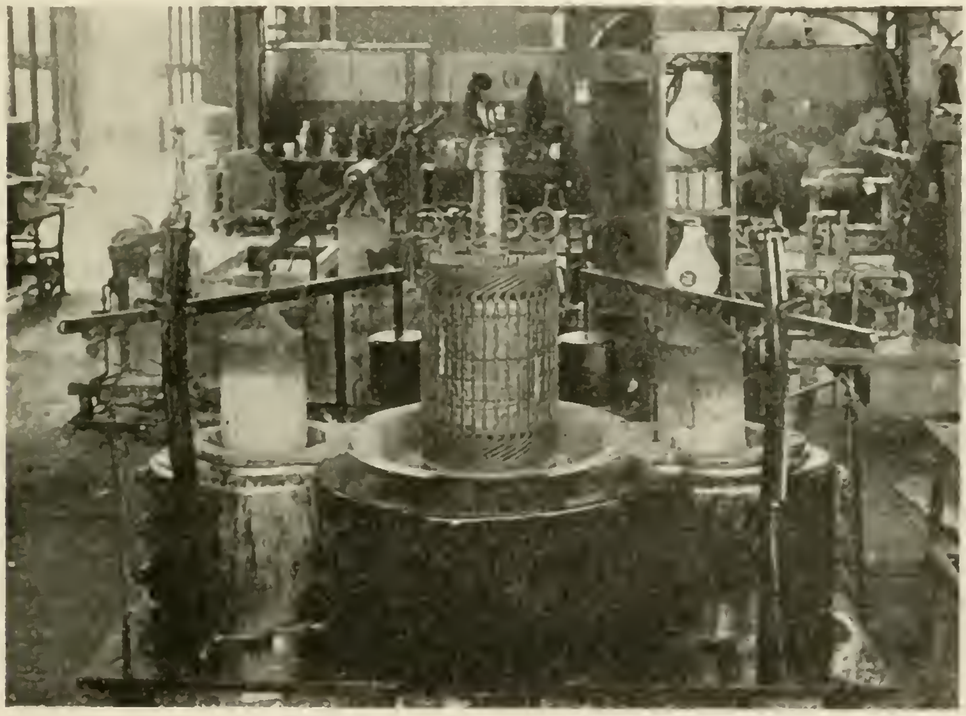


FIG. 6—SOLDERING POT FOR SOLDERING ARMATURE LEADS INTO COMMUTATOR BARS

The punchings are built upon the spider and into the frame by individual pieces, and successive layers, several inches in thickness, are given preliminary pressings under an hydraulic press. When all the laminations have been put in place, the end plates are put on and the whole is subjected to a pressure of from 60 to 70 tons in the case of the field and from 100 to 110 tons in the case of the armature. The end plates are held from turning and from coming off by keys. The completely built up field and armature core are placed upon boring mills and the inside surface of the laminations of the one and the outside surface of the other are ground to insure a perfectly true air gap.

ELECTRIC LOCOMOTIVE DRIVE

In connection with the building of electric locomotives probably the most thought and the highest skill has been devoted to obtaining a suitable means of transmitting the torque of the motors to the driving wheels. The developing of a drive for electric locomotives is a very difficult mechanical problem which has taxed the ingenuity of many, and numerous preconceived ideas have had to be modified, the experience obtained in building steam locomotives not having sufficed to give the solution.

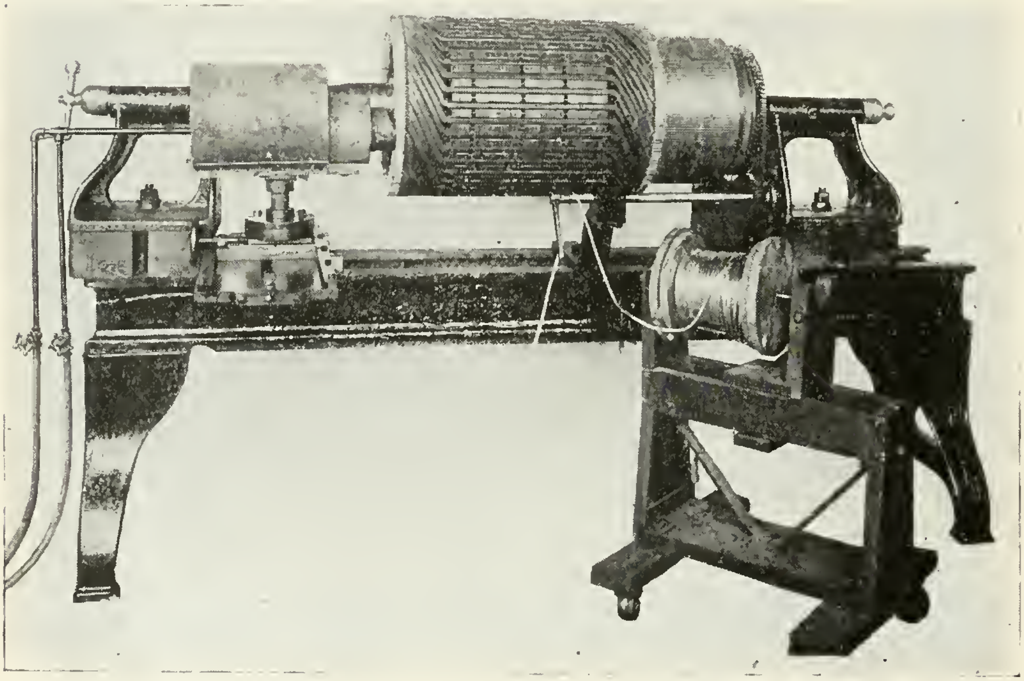


FIG. 7—METHOD OF SOLDERING REAR ARMATURE CONNECTORS OF TWO-PIECE COILS

The method of drive used for many years for ordinary electric cars, namely, a single pinion and gear, the latter pressed upon the axle, is inadequate for locomotives of more than a very limited capacity, the unit stress in the teeth of the gearing soon exceeding the point of safety. Further, the heavy weights involved in locomotive practice render some sort of spring support and drive desirable in order to relieve the track and locomotive from severe shocks incident to rapid motion over the rail joints and other inequalities of the road. These considerations were probably first met in a comprehensive manner by the drive devised for the first New York, New Haven and Hartford passenger locomotives. This drive has often been described but briefly it is as follows:—

The motors are of the gearless type, the armatures being mounted upon a quill which surrounds the axles. The field is carried by bearings upon the quill and is further supported on either side by springs and is prevented from turning by torque rods between the motor and the truck. The quill is in halves, being pressed into the armature spider from either end. Each half of the quill carries a large flange from which project seven fingers. The driving wheels are provided with seven recesses or pockets into which the quill fingers extend. The driving is done by the quill fingers, the cushioning effect being obtained by unsymmetrical helical springs surrounding the fingers and separated therefrom and from the inside of the wheel pockets by bushings to take the wear. Thrust springs are also provided, fitting into the quill fingers, which are bored out to receive them. It has been found very necessary to have the spacing of the spring pockets in the wheels very accurate and the spacing in the case of the two wheels on an axle must exactly correspond as otherwise the irregular strains would soon break the driving springs.

In assembling the motor upon the wheels and axles, the armature with the quills in place is slipped over the axle which has a wheel installed upon one end, several solid bushings are placed over the quill fingers (these bushings being of such dimensions as to make up the difference in size between the outside diameter of the fingers and the bore of the spring pockets in the wheel) and the second wheel is pressed on, the bushing on the fingers serving as guides to insure the spring pockets in the two wheels being exactly opposite. No key is needed between the wheel and the axle.

For freight or slow-speed locomotives where a gear reduction is necessary recourse has been had to a pinion on each end of the motor shaft meshing into two gears mounted upon a quill. The motor in this case is carried upon the truck frame directly above the quill and axle, and is provided with bearings fitting upon the quill to preserve the alignment; the gears are also pressed upon the quill. In order to prevent one set of gears and pinions from transmitting more power than the other set, the assembling is effected as follows:—

The motor is turned so as to bring the quill bearings uppermost; the quill with one gear on is placed in the bearing and the axle caps are tightened, care being taken that the pinion and gear are in correct mesh. The second gear is then heated and shrunk upon the quill so as to mesh exactly with the second pinion. The pinons for this drive are cut in pairs so as to be exactly alike, as are also the two gear rims. The power is transmitted to the wheels by the same principle as outlined for passenger locomotives, except the springs are supported between brackets bolted to the gears and driving wheels. In this case also the brackets supporting the driving springs upon wheels and gears must be in close relative alignment on the two sides, otherwise the life of the springs is much reduced by unequal strain and distortion. A further important feature is to have the motor so mounted as to maintain the axle at or near the center of the quill.

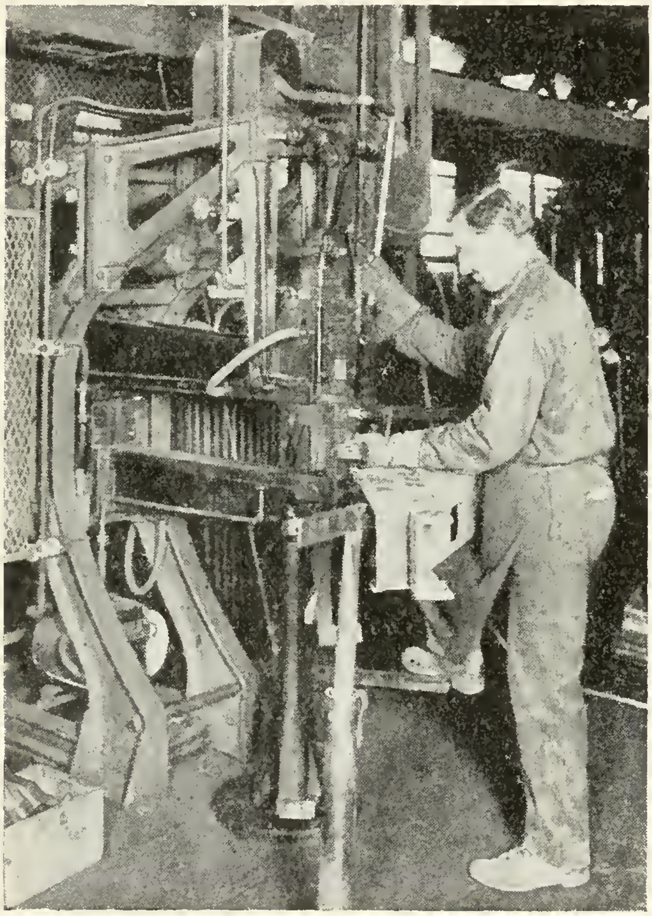


FIG. 8—SPOT WELDING SHEET IRON GEAR CASES BY ELECTRICITY

Twin Motors—An additional form of gear reduction drive that has met with considerable success has been developed in connection with the "twin motor." In this construction two motors of moderate size are so designed that their frames may be bolted together and the two are equipped with an axle or quill bearing housing in such manner that the two motors constitute one unit. Each armature of the double unit has a pinion mounted upon one end and these two pinions mesh with one gear. The method of mounting and of transmitting the power to the drive wheels is essentially the same as before described. A locomotive using twin motors usually carries four pairs of motors. The advantages gained are several, viz:—the motor units are comparatively small and easy to build and handle; it is possible to use the same motors (except frame) for heavy locomotives and for motor cars; the variety of spare parts necessary to be carried is reduced; and on the locomotives one gear takes the place of two, inasmuch as with two separate pinions driving one gear the stresses on the teeth are those produced by half the torque of the combined unit.

Flexible gears have been made and used to some extent for both locomotive and motor car work. The duty on the gearing in this service is severe and the most accurate workmanship and best materials are required.

Side Rod Drive—Owing to the recognized difficulties to be met in connection with the various gear drives there have been many advocates of the side and connecting rod drive, although the elimination of reciprocating parts has often been urged as a strong point in favor of the electric locomotives. The problem of adjusting and maintaining a side rod drive on an electric locomotive is quite different from that found in the case of the steam locomotive. In the first place there is no loose end corresponding to the piston; the connecting rods from the motor shaft to the jack shaft are much more nearly rigid and the quartering of both motor and jack shaft cranks must be exact or pounding will occur. The fit of the bearings, and particularly of the jack shaft, must be very closely maintained, or vibration and knocking are soon manifested.

In the foregoing no mention has been made of the control parts or the details of the locomotive equipments, both of which involve many and intricate problems. Enough has been said, however, to indicate the nature of the mechanical questions confronting the manufacturer of electric railway apparatus.

FLASHING IN RAILWAY MOTORS

J. A. REEVES

ONE OF THE important limiting features in the design and operation of railway motors is the flashing. If it were not for this feature, operating men could raise the voltage on their lines and manufacturers could build their motors more cheaply.

In the older motors without commutating poles, the tendency to flash was taken care of by designing the motors with very strong fields and relatively weak armatures, a liberal number of commutator bars and few turns per armature coil. A field form of a non-interpole motor having a strong field and weak armature is shown in Fig. 1. This curve represents the volts between bars on the commutator at different points between brushes. The readings for it are taken by connecting two hard pencil points to a low reading voltmeter, and reading the voltage as the points are moved across the face of the commutator, the points being separated by a distance equal to the width of one commutator bar. From this field form it can be seen that the distorting effect of the armature current is comparatively small, so that the voltage between bars is quite evenly distributed across the commutator.

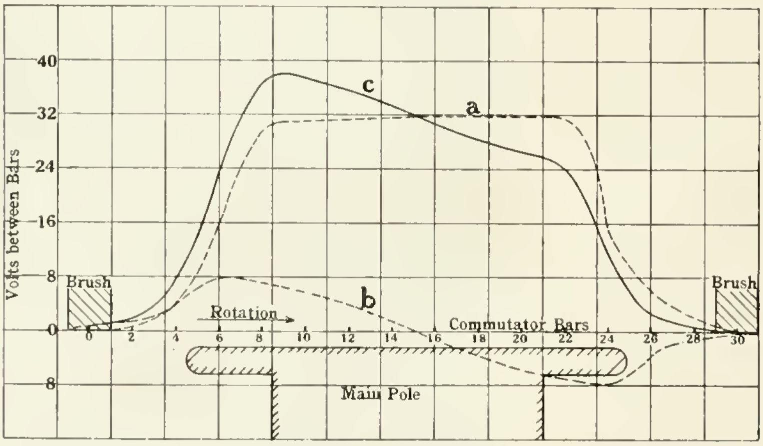


FIG. 1—FIELD FORM OF A NON-COMMUTATING POLE MOTOR WITH STRONG FIELD AND WEAK ARMATURE.
a—Main field form. *b*—Armature field form. *c*—Resultant field.

A field form of a similar machine except that the field is weaker and the armature stronger, is given in Fig. 2. This shows the effect of the distortion of the main field by the armature. The armature ampere-turns add to the field ampere-turns on the left half of the pole, sending more flux through this half of the pole than through the right half. The effect of this is that the armature coils, cutting this higher flux, will have a higher voltage generated in them than the coils cutting the flux from the right side of the pole. On the face of the commutator this will show up as higher voltage between bars near the left hand brush. The high ampere-turns at the left hand pole tip will send considerable flux out through the coil which is being commutated. This flux will tend to make the machine spark. Referring to Fig. 2, it can be seen that if a spark two bars width long, were produced from the tip of the left hand brush, it would reach out to a point on the commutator where there is a voltage of seven volts between bars. In like manner a spark four bar widths long would reach out to a point of 21 volts between bars. These voltages show that not much increase is needed to maintain this spark and carry it across the commutator.

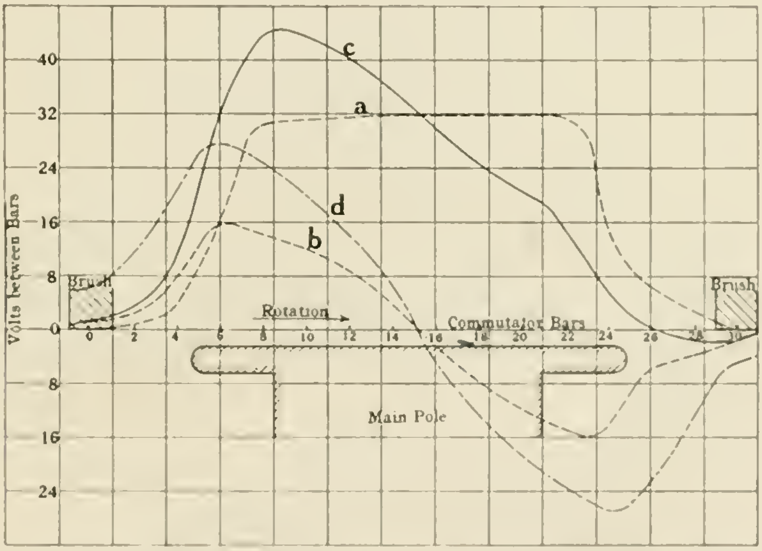


FIG. 2—FIELD FORM OF A NON-COMMUTATING POLE MOTOR WITH WEAK FIELD AND STRONG ARMATURE

a—Main field form. *b*—Armature field form—normal operation. *c*—Resultant of *a* and *b*. *d*—Armature field form caused by sudden rush of current.

Suppose the motor to be running on a certain voltage at a certain speed and this voltage is suddenly doubled, as is frequently the case in service. This causes a sudden rush of current through the motor many times more than double the current which the motor was taking. The armature ampere-turns at the pole tip, plus the field ampere-turns, increase directly with this current, and produce a flux in the armature coil being commutated which is sufficient to draw a long spark from the tip of the brush. The field form, *d*, in Fig. 2 shows how the armature flux due to this abnormal current rises in value. The flux produced by the armature ampere-turns flows around through the armature core and teeth, air-gap and main pole piece. The iron in this circuit is all laminated so that the flux responds very quickly to sudden changes in current, whereas the useful flux which produces the counter e.m.f. in the armature coils must pass around through the yoke. Since this yoke is solid cast steel the flux in it will not follow the current closely when the current increases suddenly, but there will be a slight time interval between the rise in current and the rise in flux in the frame. Until this flux rises to the value corresponding to the higher voltage which has been impressed on the machine, the counter e.m.f. will be low and the current flowing through the machine will be abnormally high. The flux caused by the armature current, however, builds up quickly and gives very high values of voltage between bars across the commutator and under the brush. The result is that the machine flashes, from brush to brush across the commutator, before the useful flux can build up and cut down the current.

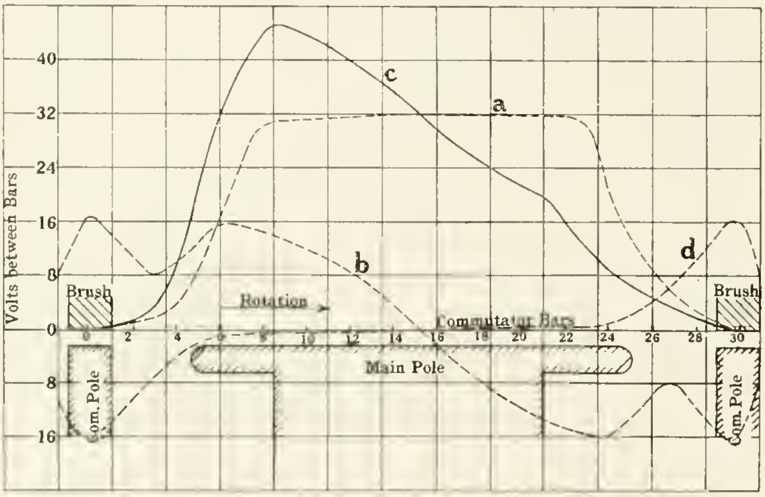


FIG. 3—FIELD OF COMMUTATING POLE MOTOR WITH WEAK FIELD AND STRONG ARMATURE

a—Main field form. *b*—Armature field form. *c*—Resultant field form of *a*, *b* and *d*. *d*—Commutating pole field form.

It is interesting to note what happens when a motor "bucks over." Once the arc is started across the face of the commutator from brush to brush, it is easily maintained by the line voltage. The armature is short-circuited by the arc and the fields are connected directly across the line. The current in the field coils, being limited only by the resistance of the coils themselves, rises to an enormous value. The flux through the armature also rises to an abnormal value, being generated by the abnormal field current. Then we have the armature, every coil of which is short-circuited at the commutator, trying to rotate through a flux which is abnormally high.

This, of course, is impossible and the armature stops rotating, causing the wheels to slide.

If the machine whose field form is plotted in Fig. 2 is fitted with commutating poles, the main field flux, commutating field flux, armature flux and resultant flux will be shown in the field forms in Fig. 3. The paths of the different fluxes in the motor with the different coils producing them is shown in Fig. 4. Within normal range of operation this machine will operate without flashing but when the voltage is suddenly increased on the motor, as in the previous case, the motor goes through the same cycle of operations as the non-commutating pole motor. The useful commutating flux must build up through the solid steel frame and commutating poles in the same way as the useful driving flux must build up through the solid steel yoke and main poles. But, as in the previous case, before these useful fluxes can build up, the flux caused by the armature current has caused the machine to "buck over."

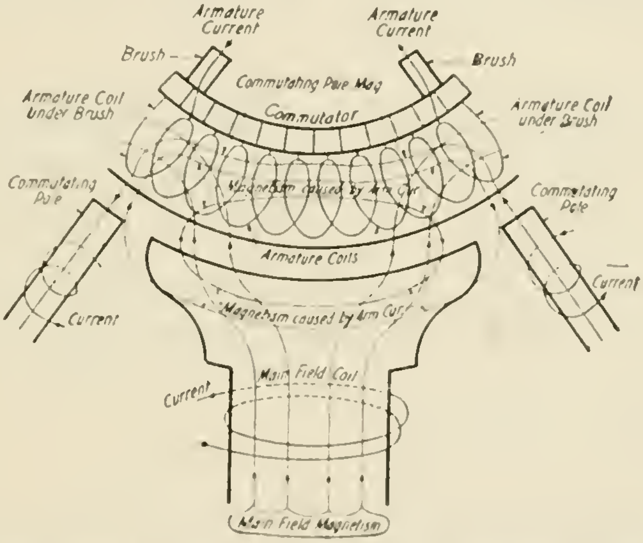


FIG. 4—DIAGRAM OF COILS AND RESULTANT FLUX IN THE MAGNETIC CIRCUIT OF A RAILWAY MOTOR

From the above it can be seen that, while commutating poles improve commutation and keep down the flashing to a certain extent, the machine must still be liberally designed from the viewpoint of flashing before it will operate satisfactorily. This means the continued use of fairly strong fields with comparatively weak armatures, a liberal number of commutator bars and few turns per coil in the armature.

A SYSTEM OF MAINTENANCE RECORDS

FOR ELECTRIC RAILWAY EQUIPMENT

T. M. CHILDS

THE system of records and reports used in connection with the maintenance of equipment on electric railway systems is of great importance, especially on the large systems where material is used and the apparatus is operated from a large number of stations. In all cases, it is of importance to know the performance of the different parts of the equipment, the relative efficiency of the men handling the material, and the results being obtained in the many departments that go to make up an electric railway system.

Such a system of records and reports not only gives the relative merits of material purchased from different concerns, but can be made to show wherein better methods can be used in applying the material to the equipment. For instance, in the methods of oiling, the head of the mechanical department will find, through the reports of different stations or individuals, that a certain method brings about far better results and a large saving in material. This method can then be called to the attention of all men in charge of the lubrication of equipment.

Oiling Record—A simple, yet very complete system for the record of oiling the equipment is shown in Fig. 1. This form is for use in each station or terminal where such work is done and, through a daily report from each station, the records in the office of the head of the mechanical department may be maintained. This form may also be used for recording the daily mileage made by each car and the time when inspection of the equipment is made. To accomplish these results, it would only be necessary to add to the symbols at the bottom of the sheet, others to be used in indicating when and what work was done on each equipment and to write the mileage in the small space under each car and day, along with the symbols. This record, at the end of each month, will then show whether equipment was inspected at proper intervals, on a daily or mileage basis, how much oil was used and the total mileage for each car and for all the equipments. A form of card to be kept on each car, showing its oiling record, for the benefit of inspectors and oilers, and also instructions for oiling equipment, is given in Fig. 2.

Record of Inspection—A simple record of the inspection of the individual equipments, indicating also the cars to be inspected, is shown in Fig. 3. This card is placed on each car to be inspected by the one in charge of such work, and is provided with a light metal holder and a hook for fastening it to some convenient part of the car. The form used on the card is so arranged as to indicate the division of work to be done by the different men and, as each portion of the inspection or repairs is made, it is so shown by the man signing his name and the date in the blank space opposite the divisions of work. The card will then show at all times what work remains to be done or when equipment is ready for service again.

RECORD OILING CARS. Month of ________________ 190__

	DAY OF MONTH																															
Car No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	REMARKS

________________________Barn ________________ Division

________________________________ Foreman

NOTE Mark O indicates Axle Bearings have been oiled that day.
" X " Journal " " " " "
" ⊗ " Both Axle and Journal Bearings have been oiled that day.

FIG. 1

OILING CARD FOR INTERURBAN CAR (MOTOR)

MONTH OF ________________ 191__ CAR NO.________________

LOCATION	DATE	Armature	Axle	Compressor	Gear	Journal	NAME OF OILER	REMARKS
Oiled Last								
	1							
	2							
	3							
	29							
	30							
	31							

SCHEDULE OF OILING

Armature Bearing, half gill every day
Axle Bearing, half gill every other day
Journal Bearing, half gill every seventh day
Gears, two pounds of grease in each gear every fifteen days.
Compressor oiled after inspection if found necessary

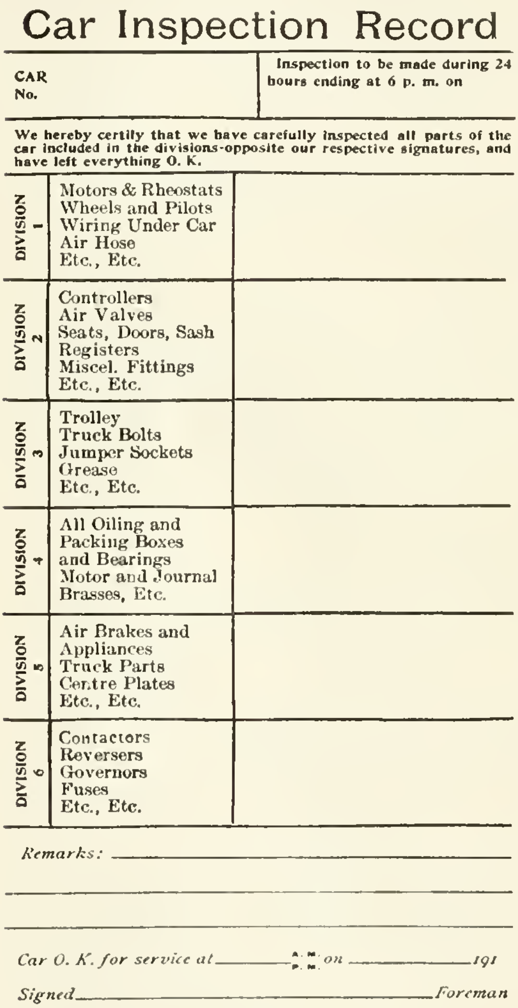
N. B.—This card must not be removed until entry has been made in the new card showing last oiling of the several parts. It must then be taken up and forwarded to the office of the Superintendent of Motive Power.

*Signed*________________________________
Foreman

FIG. 2

It also shows the time at which the car came in for inspection and when the work was completed. From such reports a more permanent record can be made by the head of the department, showing the time cars were out of service, due to inspection or repairs and the relative efficiency of the men doing the work, besides making it possible to check up failures to equipment, as the signing of the card prevents the shifting of responsibility between the men performing the different parts of the inspection.

Daily Inspection Report—A car inspector's daily report for equipment out of service each day, such as shown in Fig. 4, summarizes the individual car inspection records and forms again the basis for a more permanent record by the superintendent of equipment, such as Fig. 5, showing the time cars are out of service due to inspection or repairs, the nature of the trouble and the number of men in each shop, station or terminal. A monthly summary of this report will give a good idea of the causes for equipment being out of service and the length of time in each case.



Car Inspection Record

CAR No.	Inspection to be made during 24 hours ending at 6 p. m. on

We hereby certify that we have carefully inspected all parts of the car included in the divisions opposite our respective signatures, and have left everything O. K.

DIVISION 1	Motors & Rheostats Wheels and Pilots Wiring Under Car Air Hose Etc., Etc.	
DIVISION 2	Controllers Air Valves Seats, Doors, Sash Registers Miscel. Fittings Etc., Etc.	
DIVISION 3	Trolley Truck Bolts Jumper Sockets Grease Etc., Etc.	
DIVISION 4	All Oiling and Packing Boxes and Bearings Motor and Journal Brasses, Etc.	
DIVISION 5	Air Brakes and Appliances Truck Parts Centre Plates Etc., Etc.	
DIVISION 6	Contactors Reversers Governors Fuses Etc., Etc.	

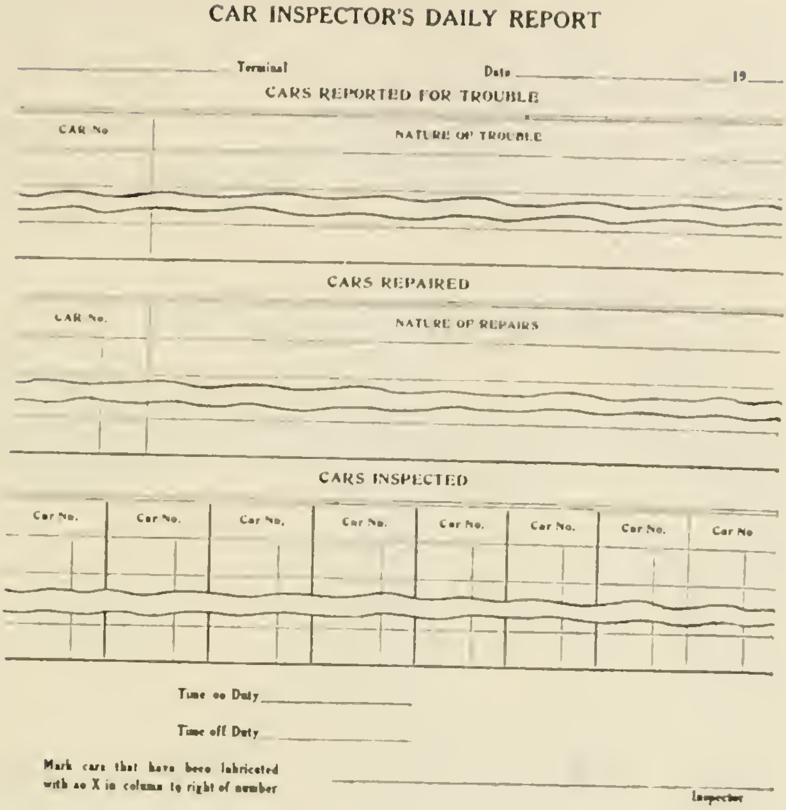
Remarks: ____________

Car O. K. for service at ________ A. M./P. M. *on* ____________ *191*

Signed ____________________ *Foreman*

FIG. 3.

Cross Reports from Transportation and Mechanical Deparments—It is often desirable to have reports coming from both the mechanical and transportation departments in regard to damaged equipment. Fig. 6 shows two forms to be used by the different departments in reporting cars which were damaged while in service. These reports coming to the head of the operating department will give both sides of the story; the one from the transportation department showing the man in charge of the car at the time of the accident and the cause for same; the other, from the head of the mechanical department, showing the labor and material



CAR INSPECTOR'S DAILY REPORT

______ Terminal Date ______ 19__

CARS REPORTED FOR TROUBLE

CAR No	NATURE OF TROUBLE

CARS REPAIRED

CAR No.	NATURE OF REPAIRS

CARS INSPECTED

Car No.	Car No.	Car No.	Car No.	Car No.	Car No.	Car No.	Car No

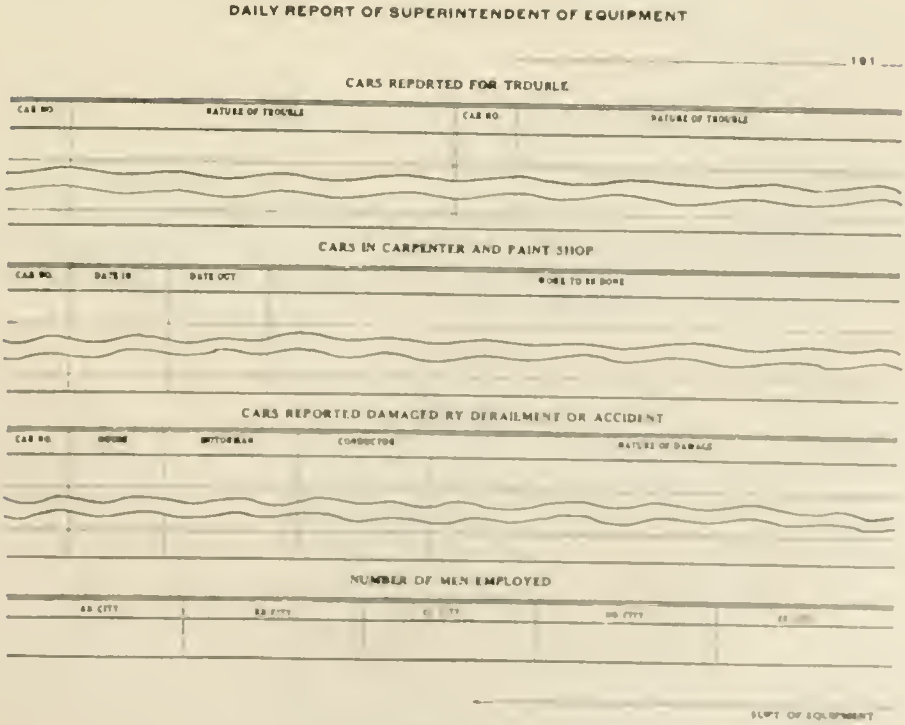
Time on Duty ______

Time off Duty ______

Mark cars that have been lubricated with an X in column to right of number

______ Inspector

FIG. 4



DAILY REPORT OF SUPERINTENDENT OF EQUIPMENT

______ 191__

CARS REPORTED FOR TROUBLE

CAR NO	NATURE OF TROUBLE	CAR NO	NATURE OF TROUBLE

CARS IN CARPENTER AND PAINT SHOP

CAR NO.	DATE IN	DATE OUT	WORK TO BE DONE

CARS REPORTED DAMAGED BY DERAILMENT OR ACCIDENT

CAR NO.	[illegible]	MOTORMAN	CONDUCTOR	NATURE OF DAMAGE

NUMBER OF MEN EMPLOYED

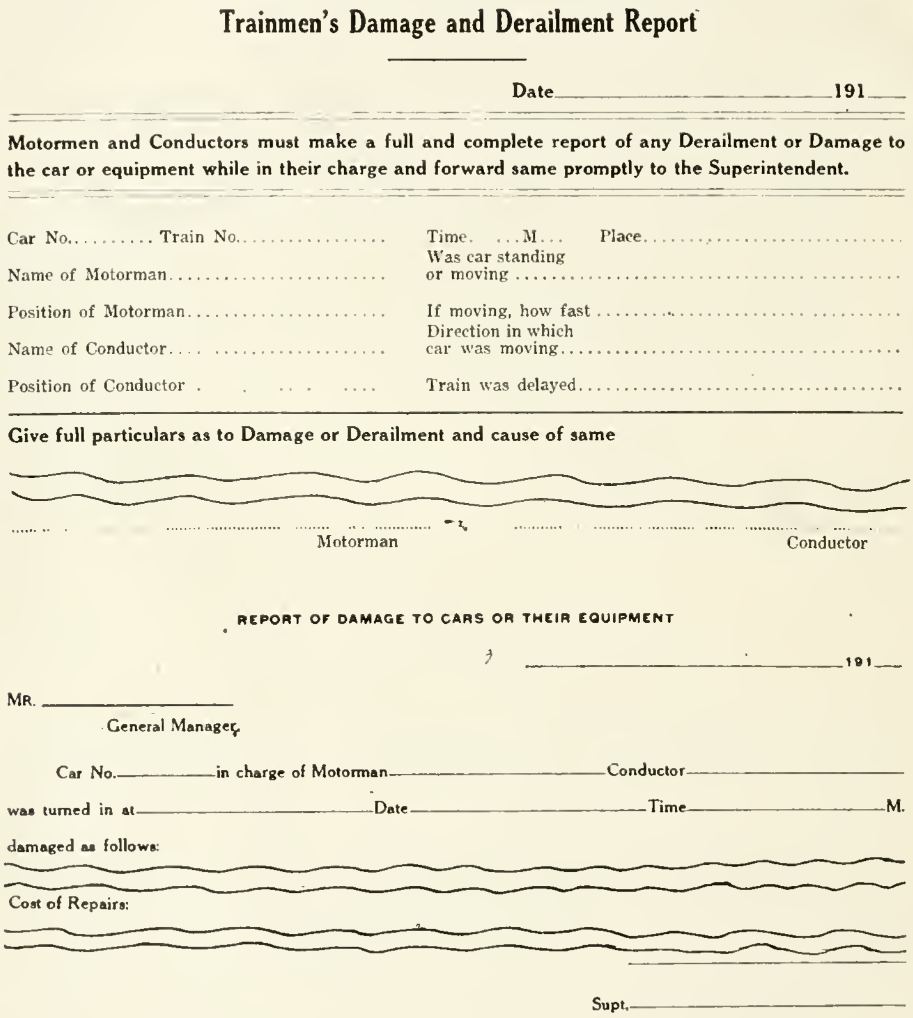
AB CITY	BB CITY	C CITY	DD CITY	[illegible]

______ SUPT. OF EQUIPMENT

FIG. 5

used, with the approximate cost for repairing the damaged parts and the probable length of time the car will be out of service.

Motorman's Report of Equipment—It is always desirable to have information of a first-hand nature come to the head of the mechanical department in regard to the equipment as it is performing in service. Fig. 7 gives a form to be filled out by each motorman upon leaving the car, which serves as an O. K. on the equipment by the man who has been operating it, or calls the shop department's attention to any defects which may be noted by the motorman. This report is to be left on the car and removed by the shop department only after repairs, if any, have been made, when it is, in turn, sent to the head of the mechanical department, with the



Trainmen's Damage and Derailment Report

Date .... 191...

Motormen and Conductors must make a full and complete report of any Derailment or Damage to the car or equipment while in their charge and forward same promptly to the Superintendent.

Car No. .... Train No. ....
Time ... M ... Place ....
Name of Motorman ....
Was car standing or moving ....
Position of Motorman ....
If moving, how fast ....
Name of Conductor ....
Direction in which car was moving ....
Position of Conductor ....
Train was delayed ....

Give full particulars as to Damage or Derailment and cause of same

.... Motorman
.... Conductor

REPORT OF DAMAGE TO CARS OR THEIR EQUIPMENT

.... 191...

MR. ....
General Manager.

Car No. ...... in charge of Motorman .... Conductor ....
was turned in at .... Date .... Time .... M.
damaged as follows:

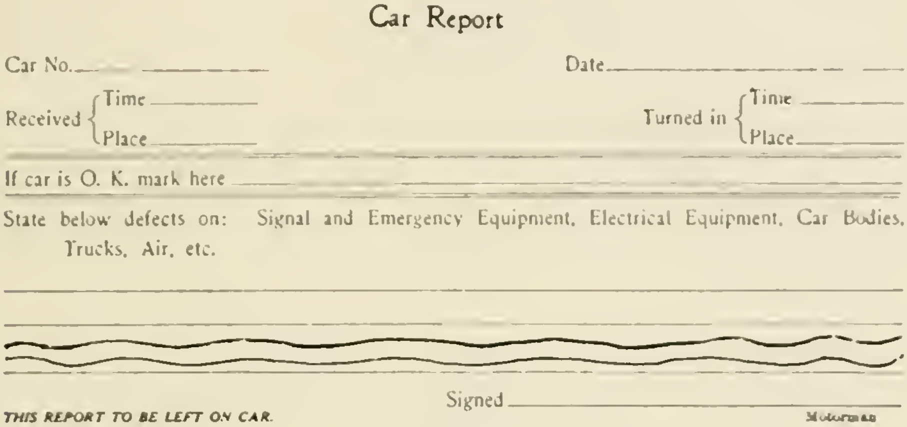
Cost of Repairs:

Supt. ....

FIG. 6

report of the man making the repairs on the equipment as reported.

Records of Parts—Figs. 8 and 9 are forms to be used for the record of each armature and field of the motor equipment. These forms contain a record of each armature and field in service and should be filed with the records of the other equipment under each individual car, giving a complete record of each part and a history of its performance. Fig. 10 shows a similar form of a record of the wheels on each axle. Duplicate tags for records of steel pinions are shown in Fig. 11, the original tag to be retained at the repair station, while the duplicate is returned to the car shop.



Car Report

Car No.________ Date________

Received { Time ________ / Place ________ Turned in { Time ________ / Place ________

If car is O. K. mark here ________

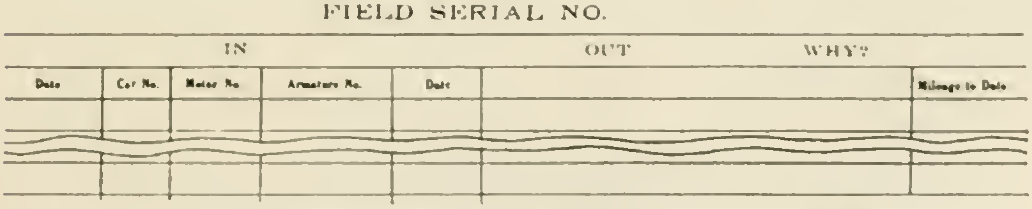
State below defects on: Signal and Emergency Equipment, Electrical Equipment, Car Bodies, Trucks, Air, etc.

Signed ________

Motorman

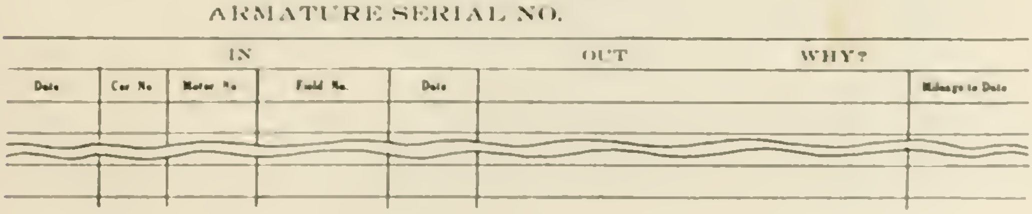
THIS REPORT TO BE LEFT ON CAR.

FIG. 7



FIELD SERIAL NO.

IN				OUT	WHY?	
Date	Car No.	Motor No	Armature No.	Date		Mileage to Date



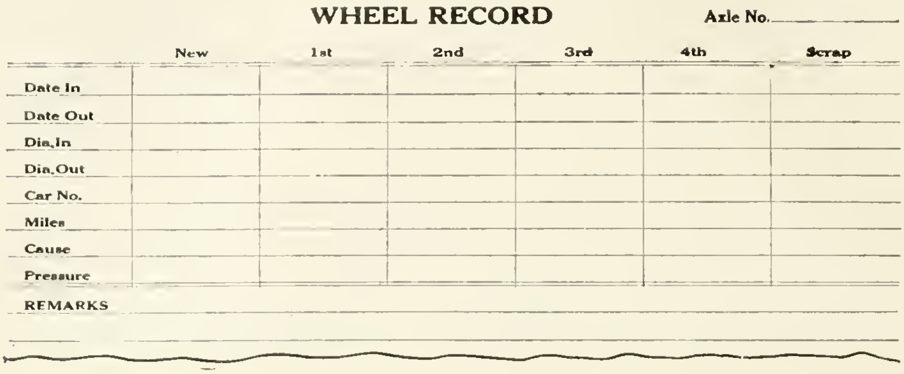
ARMATURE SERIAL NO.

IN				OUT	WHY?	
Date	Car No	Motor No	Field No.	Date		Mileage to Date

FIGS. 8 AND 9

From these tags a complete report is made up for each steel pinion, as shown in Fig. 12, which is kept with the other records of parts.

Individual Time Cards—An individual time card to be used by shop employes in turning in time at the end of each day is shown in Fig. 13, carrying with it also suggestions of the distribution of such time, according to the system of the Interstate Commerce Commission. Space is also provided below for indicating any special work engaged in and the time spent on such work, such as shop orders, etc., where it is found desirable to separate some special kind of work.



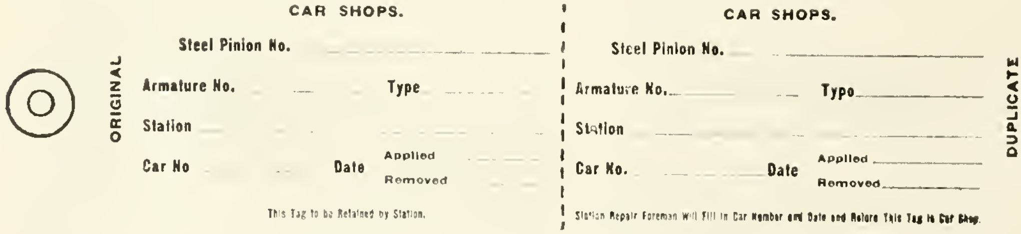
WHEEL RECORD

Axle No.

	New	1st	2nd	3rd	4th	Scrap
Date In						
Date Out						
Dia. In						
Dia. Out						
Car No.						
Miles						
Cause						
Pressure						

REMARKS

FIG. 10



ORIGINAL

CAR SHOPS.

Steel Pinion No.

Armature No. Type

Station

Car No Date Applied

Removed

This Tag to be Retained by Station.

CAR SHOPS.

Steel Pinion No.

Armature No. Type

Station

Car No. Date Applied

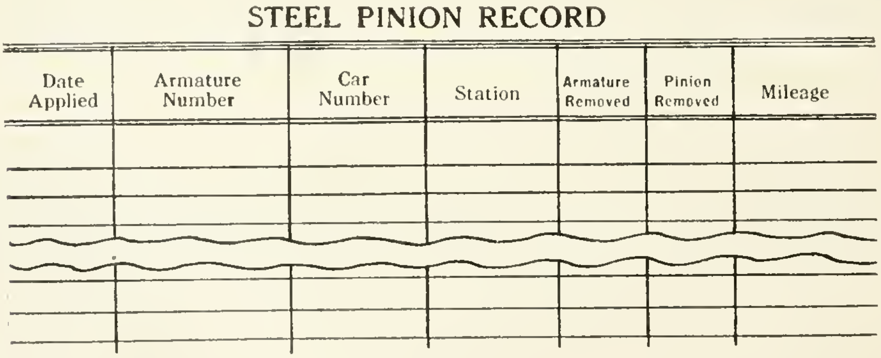
Removed

Station Repair Foreman Will Fill in Car Number and Date and Return This Tag to Car Shop.

DUPLICATE

FIG. 11

Store Room Tag—A convenient tag for use on material bins in the store room is given in Fig. 14, indicating the amount of material on hand, amount used, etc.

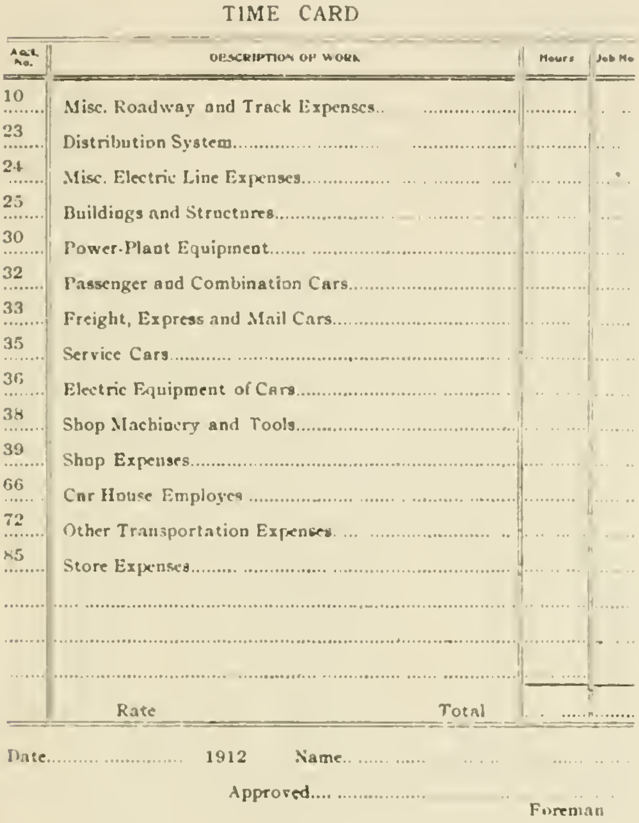


STEEL PINION RECORD

Date Applied	Armature Number	Car Number	Station	Armature Removed	Pinion Removed	Mileage

FIG. 12

System for Filing Correspondence in Mechanical Department—The filing of the correspondence used by the mechanical department of an electric railway seems to be one of the most difficult to provide for, yet a very adequate method wil be found by filing the different correspondence under the number provided by the Interstate Commerce Commission for the different accounts, as a subject for each folder. These folders may then be sub-divided, when found necessary, and as most employes are more or less familiar with the subjects and numbers of the different accounts to which labor and material are chargeable according to this system, a filing scheme with the same numbers and subjects would be one easy to become familiar with.



TIME CARD

Acct. No.	DESCRIPTION OF WORK	Hours	Job No.
10	Misc. Roadway and Track Expenses		
23	Distribution System		
24	Misc. Electric Line Expenses		
25	Buildings and Structures		
30	Power-Plant Equipment		
32	Passenger and Combination Cars		
33	Freight, Express and Mail Cars		
35	Service Cars		
36	Electric Equipment of Cars		
38	Shop Machinery and Tools		
39	Shop Expenses		
66	Car House Employes		
72	Other Transportation Expenses		
85	Store Expenses		
	Rate Total		

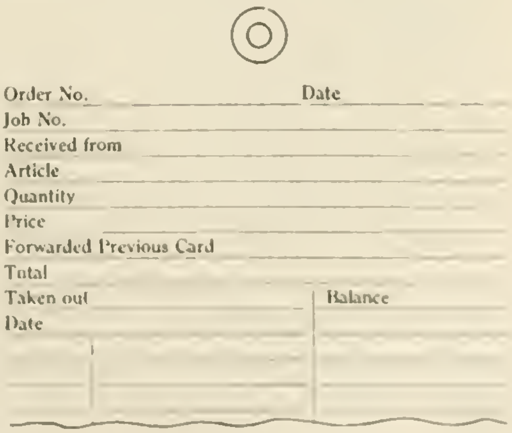
Date.......... 1912 Name..........

Approved..........

Foreman

FIG. 13

Conclusion—Necessarily, any system of forms or reports would have to be modified to suit local conditions, and the intent of this article is only to give a system of simple forms to be used for recording the inspection and maintenance of the equipment on electric cars. Numerous other forms may be provided showing the performance of the different parts of the equipment, but all should be so arranged as to totalize with ease the results found and to indicate only such information as will be of value in the future.



Order No.________ Date________

Job No.________

Received from________

Article________

Quantity________

Price________

Forwarded Previous Card________

Total________

Taken out	Balance
Date	

FIG. 14

FIELD CONTROL EQUIPMENT

OF THE MICHIGAN UNITED TRACTION COMPANY

E. A. McELHENY

THE Michigan United Traction Company is making rapid progress with the extensions and betterments recently inaugurated on its system. Fig. 1 shows a map of this system and its interurban connections, which reach many important points in Southern Michigan. These extensions and betterments include overhauling and replacing a number of their old equipments, the rebuilding of old cars, the purchase of many new cars and equipments, and the changing of the operating voltage of its interurban lines from 600 to 1 200 volts. For the interurban lines, the company is installing a total of 46 quadruple equipments of 600-1 200 volt, commutating pole motors, operated by unit-switch field control. A typical high-speed interurban car equipped for 600-1 200 volt operation is shown in Fig. 2.

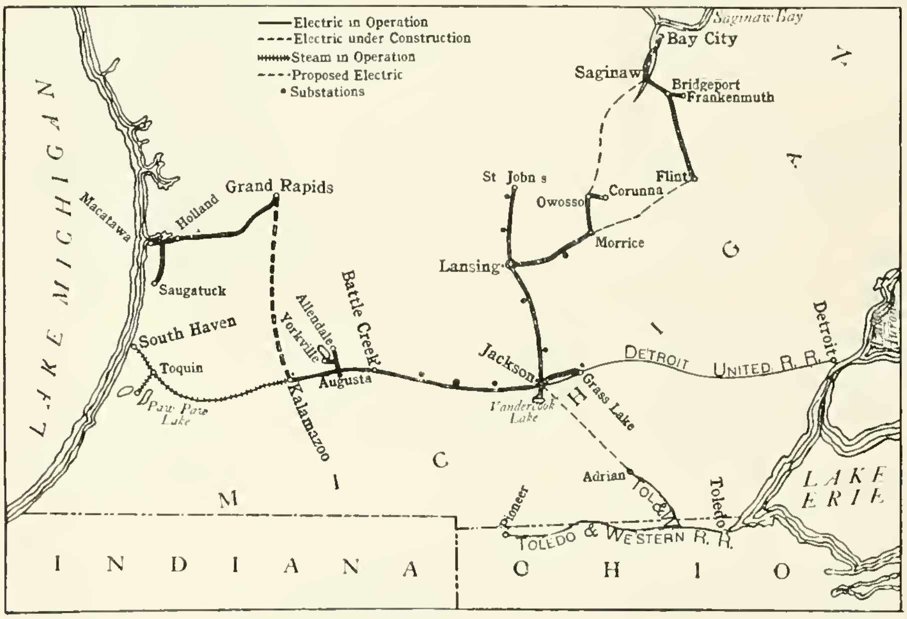


FIG. 1—MAP OF MICHIGAN UNITED TRACTION COMPANY'S SYSTEM
Jackson to St. Johns, 57.7 miles. Jackson to Owosso, 70.2 miles.
Jackson to Kalamazoo, 68.4 miles. Jackson to Grass Lake, 11.4 miles.

MOTORS

The motors used in this installation are of the box frame type with nose suspension, supplied with safety suspension lugs. Each motor has a nominal rating of 100 horse-power on 500 volts, or 115 horse-power on 600 volts. The motors are equipped with commutating poles. They are insulated for 1 200 volts, and arranged for field control. High grade materials, a good grade of insulation and the latest improvements in railway motor design have been combined to obtain a light weight motor applicable to high speed interurban service, and at the same time one adapted to economical operation in city or local service.

A great economy in the power consumption is effected by the use of field control motors. Another important advantage obtained by the use of this method of control is that motors with the same gear ratio can be used efficiently in both limited and local service. The field winding is divided so that the control equipment can cut part of the turns out of circuit as the speed increases, thus changing the number of effective turns in the motor field. A motor of this type can exert a large tractive effort at low speed, thus being able to start and accelerate a car economically; and also is able to operate satisfactorily at high speed with the same gear ratio.

These motors offer a number of features which are advantageous from the standpoint of maintenance.

1—The commutating poles insure excellent commutation at all loads.

2—The brushholders are of simple construction, easily assembled and mounted; also accessible for cleaning and inspection.

3—Bronze shells lined with babbitt are used for the armature bearings, and the axle bearings are of bronze with the bearing surfaces tinned. All bearings are lubricated by the oily waste system. Each oil well has a separate gauging well by means of which the amount of oil in the bearings is easily determined, and all bearings can be kept well lubricated with very little attention on the part of the inspector.

4—The weight of the motor on the axle is carried almost entirely by the extension of the frame which fits over the axle. The split between the frame and the axle caps is such that there is practically no strain on the axle cap bolts. The axle and axle bearings are protected from dust and dirt by means of sheet steel dust guards which are fitted over the axle and between the two axle bearings. These are very effective in increasing the life of the axle bearings, axles and gears.

5—Ribbon wound armature coils give a very solid and compact construction. The use of ribbon copper gives approximately 10 percent greater cross-section than round wire for a given space.

CONTROL EQUIPMENT

The control for these equipments offers several new and interesting features. On different divisions of the Michigan United Traction Company's extensive system, it is necessary that the equipments obtain their power either from a trolley or a third rail, and that they operate at full speed on either 600 or 1 200 volts.

Twenty of the equipments are intended for operation on 600 volts at the present time, and these equipments are built for this service, but so arranged that, by the addition of a change-over switch and a few minor changes in the wiring, they can readily be changed for 600-1 200 volt operation, when desired.

Twenty-six of the equipments are for use on the Kalamazoo and Lansing division, where they will replace a number of quadruple equipments of old motors. These equipments include an electro-pneumatically operated main change-over switch for changing over the dynamotor and main circuits for operation on either 600 or 1 200 volts, and an electro-pneumatically operated shoe and trolley change-over switch for changing from third rail to trolley operation or vice versa. These switches are interlocked electrically, so that neither can be thrown while power is being applied to the main circuits, nor can one be operated unless the other be fully thrown in one of its two positions.

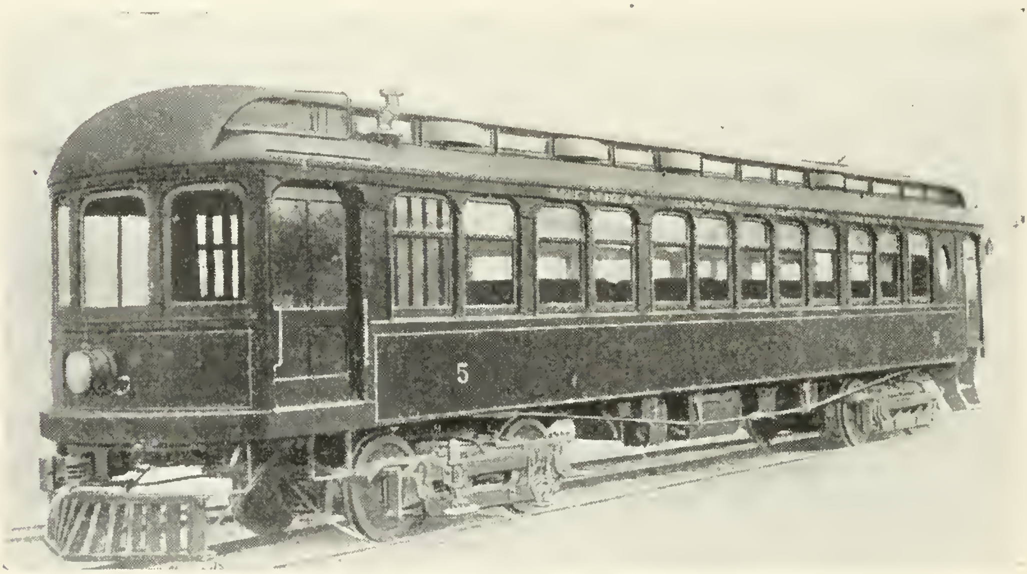


FIG. 2—HIGH SPEED 1 200 VOLT INTERURBAN CAR.

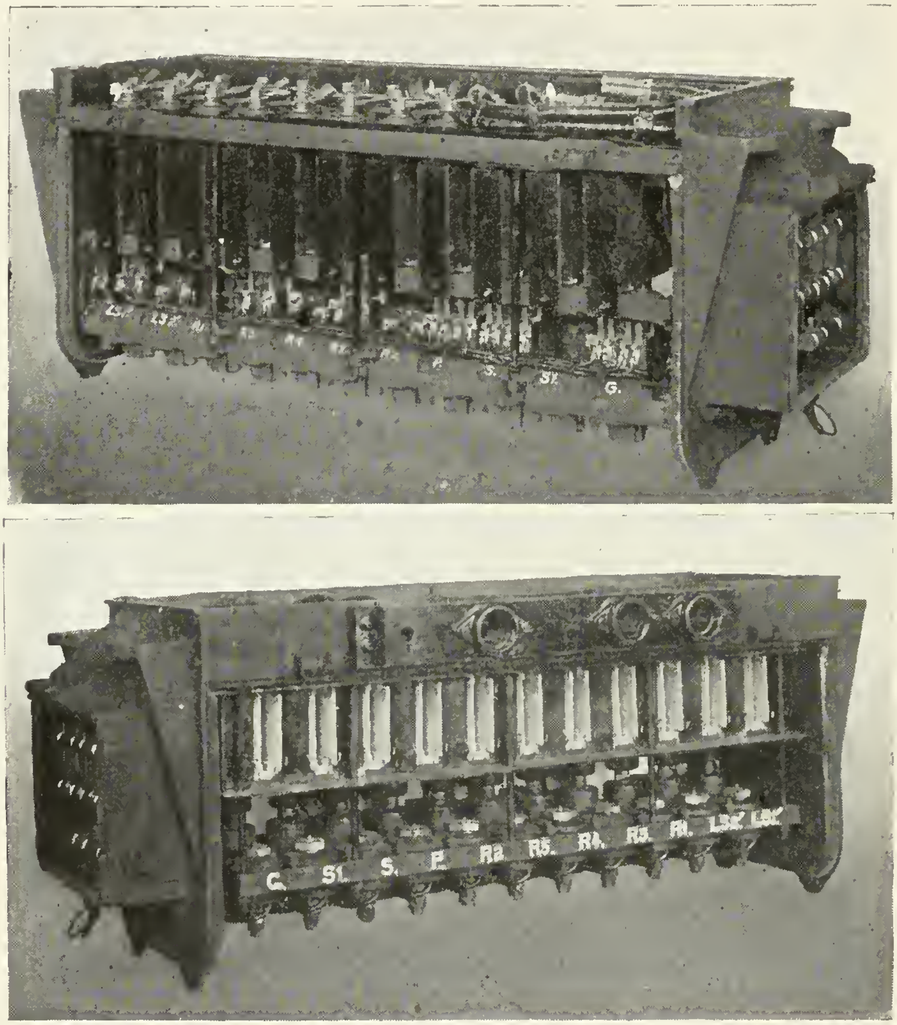
The shoe and trolley change-over switch is of the same general type as the field change-over switch and reverser. This change-over switch has ample current carrying capacity for operating a train of three cars from a single trolley or set of shoes, and has been carefully designed for operation on 1 200 volts. Its contacts are overlapped so that the change from third rail to trolley can be made without interrupting the dynamotor or lighting circuits, providing the third rail and trolley are of the same voltage at the point where the change is made.

The main change-over switch is arranged so as to connect two motors permanently in series and the sections of the grid resistor in series for 1 200 volt operatoin, while for 600 volt operation it connects two motors permanently in parallel and parallels the sections of the main resistor. This arrangement permits the operation of the motors at full speed on either 600 or 1 200 volts. The dynamotor circuits are supplied with blow-out coils so that the change-over switch can be operated without stopping the dynamotor or cutting off the lights.

The various main circuit connections on each car are made by means of a total of thirteen pneumatically operated unit switches. Eleven of these form the switch group, and two, mounted in a separate frame, are used as line switches. The control wiring is so arranged that eight of these switches are controlled by the action of the overhead trip relay which, when actuated, opens the control circuits for these switches and insures a number of breaks in series in case of an overload or short circuit. The motors are operated with full fields on all steps except the last step in parallel, on which notch the connections are changed from "full field" to "normal field." Moving the master controller to the last position energizes certain control circuits which in turn effect this change from full field to normal field.

The operation of the train is governed by a master controller which controls the operation of the magnet valves, and thus directs the movement of the switches, reverser and field change-over switch, thereby regulating the operation of the motors. The cars are all equipped for single end operation. The master controller has a total of eleven notches; six in "series," and five in "parallel," and includes the so-called "dead-man's handle" feature. From the master controller, the control circuits are carried to a multi-conductor train line from which branch circuits are run to each piece of apparatus. This train line extends the entire length of each car and terminates in two twelve-point receptacles at each end of the car. The train line of any car may be connected to that of any other car, at either end, by means of two twelve-conductor jumpers placed in the receptacles. When this is done, the train line is then made continuous through all of the cars. Operating the master controller on any car under these circumstances, operates the respective pieces of apparatus on all cars simultaneously. As a matter of convenience, the connections between the train line and the branch control circuits to the several pieces of apparatus are made in junction boxes.

A unique feature of these equipments is the arrangement of the train line receptacles. There are three of these receptacles, two for the train line and one for the bus line circuits, and they are supported by the radial draw bar. This arrangement necessitates only one set of receptacles on each end of the car, in place of two sets in multiple, as is required where the receptacles are located on the dash, and very short jumpers are used which cross under the couplers. Only twelve wires are necessary for the usual field control, but in this case two extra wires each are required for train operation of the main, and shoe and trolley change-over switches. In addition to these, extra wires were required for the operation of signals and for synchronizing the compressors. A 1 200 volt bus line receptacle and jumper are used for supplying power for heating and lighting the trail cars, or for operating motor cars in trains with only one trolley raised. The bus line receptacle is mounted



FIGS. 3 AND 4—FRONT AND REAR VIEW OF UNIT-SWITCH GROUP FOR FIELD CONTROL

Used by Michigan United Traction Company.

under the draw-bar between the two train line receptacles.

Compressed air for operating the switches, reverser and change-over switches is obtained from the air brake system through a reducing valve set for 70 pounds pressure. The air is admitted to or released from the cylinders through electrically-operated magnet valves attached to the cylinders. Power for operating the magnet valves is obtained through a shunt circuit from a control resistance which is connected to the trolley by the master controller on 600 volts, but on 1 200 volts this control resistance is connected to the 600 volt tap of the dynamotor.

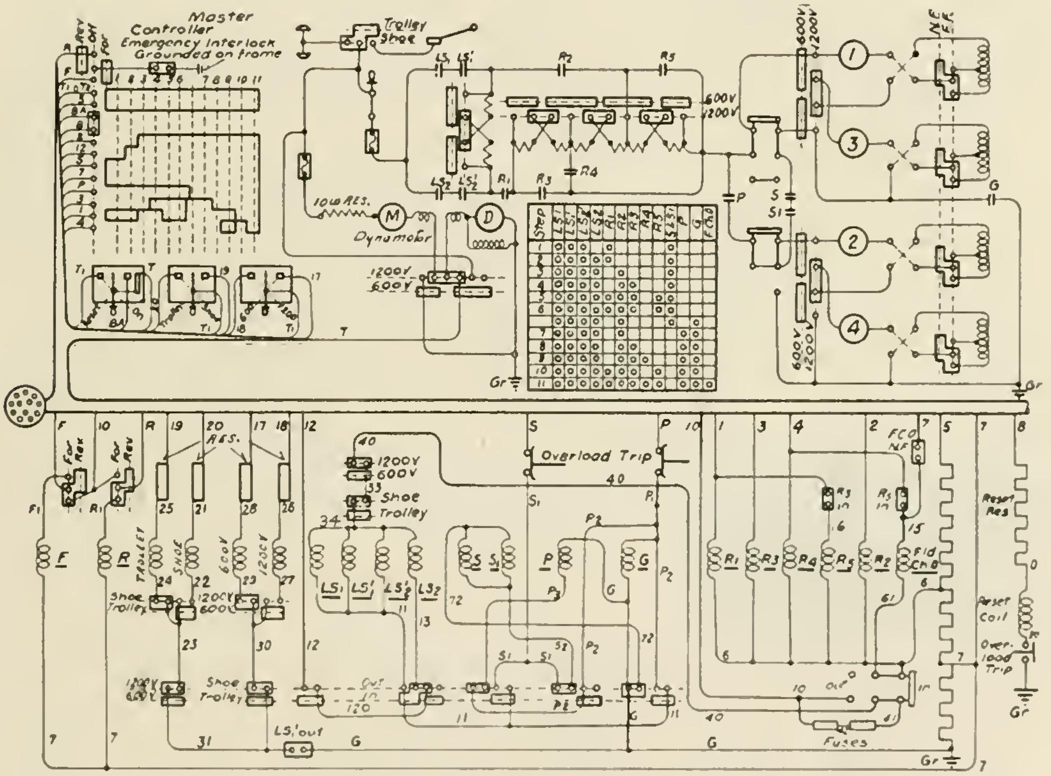


FIG. 5—DIAGRAM OF CONNECTIONS OF UNIT-SWITCH FIELD CONTROL SHOWN IN FIGS. 3 AND 4

The dynamotor and compressor are combined into a single piece of apparatus called the dynamotor compressor, which furnishes low voltage current for the lighting and control circuits, and also supplies air for the air brake system. The dynamotor runs continuously, but the compressor part of the unit operates only when necessary to keep up the air pressure, and is controlled automatically by the action of a governor.

The train line is rendered safer, and, in fact, the whole equipment more reliable, by the arrangement of the control resistance. This resistance is not connected in series with the maget coils, but is connected in shunt across the line when the master controller is "on." The magnet coils are operated from a low voltage tap on the resistance. Thus, normally, only one of the train line wires carries full trolley voltage, while the remainder are subjected to voltages of one-third or less, instead of all the auxiliary circuits being operated at full line voltage, as is usual in some systems of line operated control.

The control resistor is made up of strips of slotted steel ribbon insulated with mica and enclosed in flattened sheet iron tubes. These resistance elements are similar to flat-iron heating elements, and this arrangement gives an exceptionally substantial and reliable resistance.

The grid resistors are similar in construction to the standard resistors for 600 volt equipments, except that the insulation between individual grids and between grids and end frames has been increased for 1 200 volt service.

Overload protection is afforded by the line switch, which, in connection with an overload trip relay, acts as a circuit breaker. In case of an overload or short circuit, the action of the overload trip will open these switches as well as certain switches in the switch group, and thus cut off the power. The function of these switches, however, is not merely that of a circuit breaker which opens only under overload or short circuit, but they also open every time the handle of the master controller is returned to the "off" position, so that, in addition to the opening in case of short circuit, they assist in opening the circuit under normal operating conditions. Whenever the overload trip operates, the switches opened cannot be closed again until the trip has been reset by moving the control switch to the "reset" position or by manually releasing the latch on the trip.

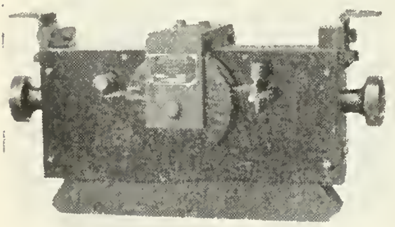


FIG. 6—MAGNETIC BLOW-OUT FUSE BOX

To provide the additional protection for the equipment against overloads and short circuits, a copper ribbon fuse is used. This fuse is enclosed in a fuse box which is supplied with blow-out coils arranged with properly placed iron parts of the box to give a powerful blow-out effect on any arc due to the blowing of a fuse. This box is designed to have ample current capacity for 600 volt operation, and at the same time sufficiently powerful blow-out effect to give excellent results on 1 200 volts.

INTERURBAN ELECTRIC LOCOMOTIVES

D. H. ACKERSON

IN THE OPERATION of interurban systems, it is likely that no problem has received more thought, or has involved greater difficulties than the economical handling of freight traffic. Many factors are to be considered, including the necessity of adequate terminal facilities, regulations of commerce, city ordinances limiting operation, etc. On the ordinary interurban system, the primary condition imposed is to handle freight by the running of additional trains, with a sub-station and distributing system already loaded to capacity and with but little outlay permissible. Therefore, minimum power consumption and low peak loads are essential.

SELECTION OF LOCOMOTIVE

The maximum allowable current should be known and the locomotive and size of train proportioned to fit this requirement within a reasonable limit. An important decision to be made in the beginning is the determination of the weight of the locomotive.

TABLE I—COMPARISON OF CHARACTERISTICS OF HIGH AND LOW SPEED MOTORS.

No. 1	Motor	No. 2
600	Volts	600
670	R. P. M.	300
246	Full-load current in amperes	152
175	Horse-Power	100
3550	Tractive effort in pounds	4550

Among the other factors, the weight of rail, condition of ballast and maximum weight the bridges will stand, should be considered. The weight of the locomotive selected should obviously be properly proportioned with the motor equipment, so that if an attempt is made to pull excessive overloads, the driving wheels will slip and no harm result.

For the sake of illustration, consider two motors of like weight and size, wound for different speeds, of the characteristics shown in Figs. 1 and 2. A comparison of the characteristics of these two motors is given in Table I. To compare the performance of two locomotives of like weight, equipped with these two types of motors, consider locomotive No. 1 equipped with four high-speed motors, having the characteristics shown in Fig. 1, and locomotive No. 2 equipped with four slow-speed motors, with characteristics as in Fig. 2. Both equipments have a gear ratio of 17:60 with 33-inch wheels, and both locomotives weigh 45 tons, all on the drivers.

From Table II it will be seen that locomotive No. 1 will pull 38 cars weighing 45 tons each at a speed of 9.2 miles per hour, as against 19.1 miles per hour; the slow-speed locomotive requires but 928 amperes during acceleration, as against 1 800 on the part of the higher speed locomotive. The sacrifice is in the locomotive speed, and as a rule high locomotive speeds are not required.

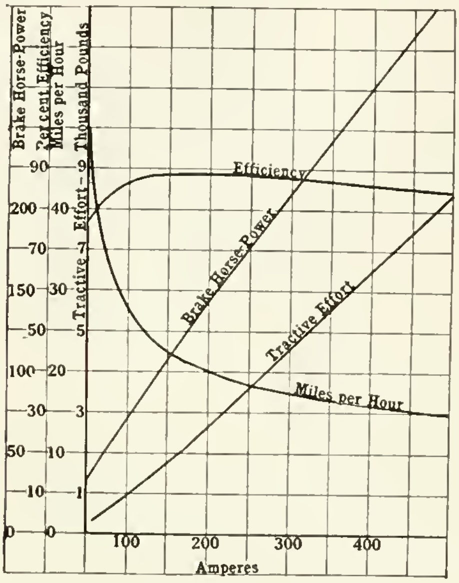


FIG. 1—CHARACTERISTIC CURVES OF HIGH-SPEED MOTOR

Applicable to ordinary interurban passenger service.

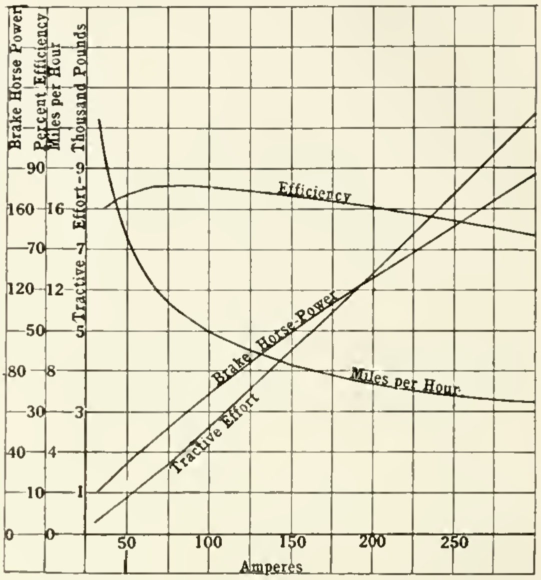


FIG. 2—SIMILAR CURVES FOR A SLOW-SPEED MOTOR

Suited to locomotive freight service.

The relation between the above locomotives as to speed and hauling capacity on the basis of a definite current demand at starting is shown in Table III; while the virtue of slow-speed windings to affect a definite haul at a reduced current consumption is indicated in Table IV. The basis taken is a haul of a definite trailing load of 675 tons.

TABLE II—COMPARATIVE PERFORMANCE OF HIGH AND LOW SPEED LOCOMOTIVES OF EQUAL WEIGHT

No. 1		No. 2
30000	a—Max. tractive effort, lbs. (starting with sanded rail)	30000
38	b—Max. number of 45-ton cars which can be started on level track, based on (a)	38
11950	c—Running draw-bar pull, lbs., with same trailing load as in (b)—1710 tons	11950
19.1	d—Balancing speed, miles per hour at 600 volts corresponding to (c)	9.2
1800	e—Starting current per locomotive, amperes	928
450	f—Starting current per motor corresponding to (a), amperes	232

Inasmuch as the question of motor capacity is largely one of temperatures, forced ventilation has been used effectively in obtaining a maximum output. The continuous rating of railway motors varies ordinarily from 45 to 50 percent of the one hour rating, and through the medium of forced ventilation, this has been increased to 60 to 75 percent of the one hour rating. The continuous capacity of the motor equipment is increased by 45 to 60 percent of that obtained with natural ventilation.

TABLE III—COMPARISON OF SPEEDS AND HAULING CAPACITY FOR GIVEN CURRENTS

No. 1	Locomotive	No. 2
232	Assumed current in amperes per motor	232
928	Maximum accelerating current in amperes per locomotive	928
3250	Starting tractive effort per motor, lbs.	7500
13000	Starting tractive effort per locomotive, lbs.	30000
16	Trailing load—No. of 45-ton cars	38
24.4	Balancing speed at 600 volts on level tangent in miles per hour	9.2

TABLE IV—COMPARISON OF SPEEDS AND CURRENT FOR GIVEN HAULING CAPACITY

No. 1	Locomotive	No. 2
15 cars at 45 tons each 675 tons total	Trailing load	15 cars at 45 tons each 675 tons total
12 600	Accelerating tractive effort per locomotive on level track, lbs.	12 600
3 150	Accelerating tractive effort per motor, lbs.	3 150
900	Accelerating current per locomotive	468
225	Accelerating current per motor	117
24.6	Balancing speed on level tangent in miles per hour	12.4

While the electrical characteristics of a motor equipment for locomotive service are of utmost importance, mechanical considerations are at least as important. Among the important features incorporated in modern designs are spider armature construction, tending to greatly reinforce the armature shaft; spring packed field coils, to eliminate vibration of this element; bolted-type commutators, to eliminate loose bars; strap wound armature and field coils, affording a great rigidity and increased space economy; box frame motors with overhung frames; superior insulation; and rigid two-point suspension of gear cases.

TABLE V—TRAILING LOAD IN CARS OF 45 TONS EACH AT ONE HOUR RATING

No. 1	Grades—Percent	No. 2
38	level	38
17	½	22
10	1	14
6	2	7
3	4	4

The effect of grades on the hauling capacity of locomotives is in many cases a determining feature. On a grade the resistance due to friction is increased by that due to lifting a train against the force of gravity. Assuming a locomotive resistance of 15 pounds per ton, a car resistance of seven pounds per ton and an accelerating force of ten pounds per ton, Table V shows the severe effect of grades in reducing the weight of the train which may be hauled by the locomotive at the hour rating of its motors. Referring to Table III it will be seen that the extreme limit for level tangent track is 38 cars, based on an adhesion limit of 33 1/3 percent.

While the figures for hauling capacity on grades correspond to the hour ratings of the motors, it should be understood that this is not an absolute indication of the motors' real capacity, as the motors may be already warm when reaching the grade, but, on the other hand, it will require considerably less than an hour to get the train over the ordinary grades found in interurban work. Therefore, it is permissable to use this value for comparative purposes only, as shown in Table V.

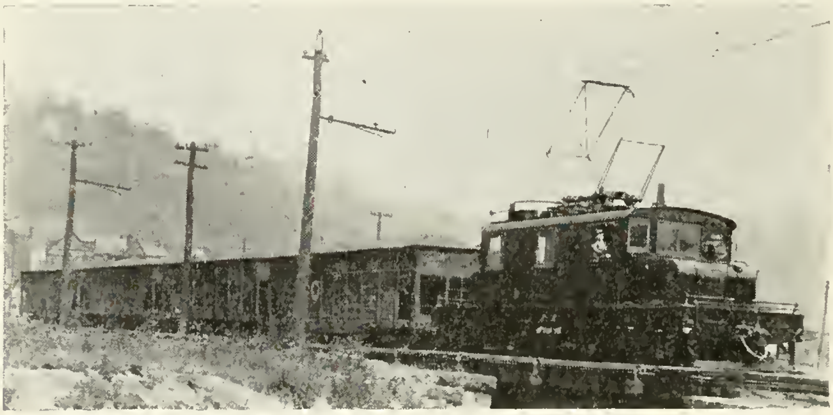


FIG. 3—SIXTY-TON LOCOMOTIVE, FOR SWITCHING SERVICE
On the Niagara Junction Railway.

A considerable prejudice exists in some localities against freight haulage, due to the excessive drop in line voltage, accruing from the hauling of heavy loads with motor equipments of comparatively high armature speed, and small gear reduction. The voltage conditions obtained during a given operation must of necessity receive close attention and the distinct reduction in line drop with locomotives equipped with slow-speed motors is not only of interest, but of considerable value in permitting the haulage of heavy trains.

To illustrate this condition assume a section of trolley and distribution system, ten miles in length with a rotary converter station at each end; a trolley consisting of one line of No. 0000 B. & S. wire; a feeder consisting of one line of 300 000 circ. mil cable and rails weighing 70 pounds per yard and bonded. The drop in potential for the feeder and trolley system is 10.75 volts per mile, per

100 amperes. The drop in potential for the track or return circuit is 3.5 volts per mile, per 100 amperes. The total drop in potential for the outgoing and return circuit is therefore 14.25 volts per mile, per 100 amperes. The line drop is to be figured for both starting and running conditions, with a trailing load of fifteen 45-ton cars, or 675 tons, with the locomotives considered in previous tables.

Case I—Train half-way and current equally divided between substations.

Voltage drop per 100 amperes = 5 (miles) × 14.25 (volts per mi.) = 71.25

No. 1	Locomotive	No. 2
Starting		
900	Line current in amperes	468
450	Line current from each sub-station	234
$4.5 \times 71.25 = 321$	Line drop-volts	$2.31 \times 71.25 = 167$
Running		
504	Line current in amperes	260
252	Line current from each sub-station	130
$2.52 \times 71.25 = 179$	Line drop-volts	$1.30 \times 71.25 = 93$

Case II—Train 2.5 miles from one substation and 7.5 miles from the other. Current will be divided between substations in the ratio of 75 percent from the nearer and 25 percent from the farther station.

Volts drop per 100 amperes to nearer station = 14.25 × 2.5 = 35.67

Volts drop per 100 amperes to farther station = 14.25 × 7.5 = 107

No. 1	Locomotive	No. 2
Starting		
900	Line current in amperes	468
$0.75 \times 900 = 675$	Line current from nearer sub-station	$0.75 \times 468 = 351$
$6.75 \times 35.67 = 241$	Line drop-volts	$3.51 \times 35.67 = 125$
$0.25 \times 900 = 225$	Line current from farther sub-station	$0.25 \times 468 = 117$
$2.25 \times 107 = 241$	Line drop-volts	$1.17 \times 107 = 125$
Running		
504	Line current in amperes	260
$0.75 \times 504 = 378$	Line current from nearer sub-station	$0.75 \times 260 = 195$
$3.78 \times 35.67 = 135$	Line drop-volts	$1.95 \times 35.67 = 70$
$0.25 \times 504 = 126$	Line current from farther sub-station	$0.25 \times 260 = 65$
$1.26 \times 107 = 135$	Line drop-volts	$0.65 \times 107 = 70$

There has in the past been a considerable feeling that the horse-power rating of a motor should have precedence in the selection, but broader experience has proven this to be a fallacy, and the above examples will show that the selection should be influenced largely by proper speed characteristics of the motor equipment.

LOCOMOTIVE EQUIPMENTS

Since an entire train is dependent upon the reliability of the engine, the continuity of service of a locomotive is of vital importance. During the past several years great strides have been made in the perfection of control equipment, and at the present time control apparatus is available which affords a reliability in service and economy in maintenance equaling that of the best railway motors. The tendency has been decidedly in the direction of remote control, due to the ability to carry heavy currents, prevent arcs and decrease the element of danger and cost of maintenance.

In developing control apparatus to the present state of efficiency, the following points have been given considerable attention:—

1—To secure positive operation under all voltage conditions and loads imposed
2—To permit the frequent opening of power circuits, without undue burning on contacts or switch box sides.
3—To secure ready accessibility of working parts, thus decreasing the cost of up-keep.
4—Heavy springs insure the opening of the switch when desired, which, together with heavy magnetic blowouts, reduces the burning on switch parts to a minimum.

These features are made possible through the use of compressed air, which, in itself, affords a high contact pressure, increasing considerably the current to be handled reliably with a given contact surface and at a given heating.

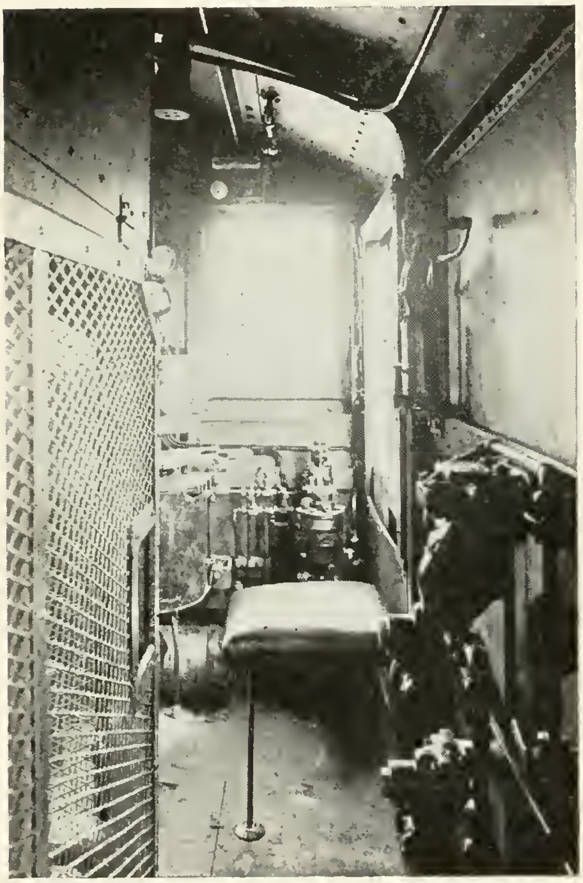


FIG. 4—MOTORMAN'S STATION ON A 60-TON LOCOMOTIVE

The ability to operate control apparatus on extremely low line voltage and with no reduction in switch contact or pressure, is of prime importance in locomotive service. The maximum voltage drop is at just the time the locomotive is drawing the heaviest currents from the line and when heavy contact pressures are most needed. Through the medium of electro-pneumatic control, a constant pressure is kept on switch contacts.

High power pneumatically-operated reversers have, by reason of inherent construction, proven particularly well adapted to the heavy locomotive service. Pressures of approximately thirty pounds are used on the contacts and segments, which result in wiping off any ordinary burr or scar that may be encountered in service.

There is, further, the point of adequate motor protection, and along this line, overload trips have been adopted to act as circuit breakers, which are dependent primarily on the magnetic action of coils, translating the motor current to a mechanical force, and tripping the mechanism at the setting desired. With this device, the only variable is the air-gap and for a given adjustment, there is no appreciable variation.

In the operation of modern railroad trains, the art and practice of braking has, perhaps, taken precedence over the other features. The many factors of safety and reliability are largely dependent upon the proper selection and operation of the brake equipment. Further, to secure a maximum hauling capacity and, therefore, the greatest economy in operation, the air brakes must show accuracy and reliability in train haulage.

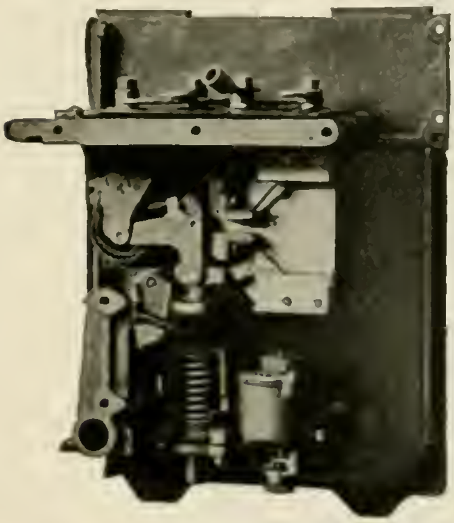


FIG. 5—SECTION OF ELECTRO-PNEUMATIC SWITCH

Electric locomotives require automatic brakes of the most approved type for the handling of trains and, at the same time, demand the flexibility of straight air brake equipment when operating as a single unit. To insure a smooth handling of train and avoid damage to lading and rolling stock, there must be an extreme flexibility of service operation, which requires a further flexibility in the control of the brake cylinder pressure between maximum and minimum values.

In the equipping of electric locomotives, there is, of course, the fundamental consideration of arranging all apparatus so as to properly perform its function and to prevent even the slightest possibility of trouble. Another consideration is the economical placing of all parts for easy inspection and adjustment, and the elimination of noise. The "central arrangement" of apparatus has come into favor as accomplishing these ends. In this method, the power circuit control apparatus and the grid resistances are mounted in the center of the locomotive cab, surrounded by screens which serve as a protection against accidental contact, and, at the same time, give a good view of the apparatus. The grid resistors are located near the roof, which permits the heat to rise and pass directly out through the ventilators, so that little of the heat reaches the other pieces of apparatus. There is a distinct advantage in placing all the control apparatus in one part of the locomotive rather than scattering it in various locations. The protective screen can readily be removed to allow easy access to the control parts for adjustment or repair.

The location of the compressor or blower motors under the locomotive hood removes the feature of objectionable noise inside the cab. These motors can be inspected or lifted out by removing the hood doors or the hoods without disturbing other apparatus.

In the right hand corners of the cab are mounted the master controller, engineer's brake valve, control switch and any other devices necessary for immediate control by the motorman, all being so located as to allow the motorman a clear view of the track regardless of the direction of running.

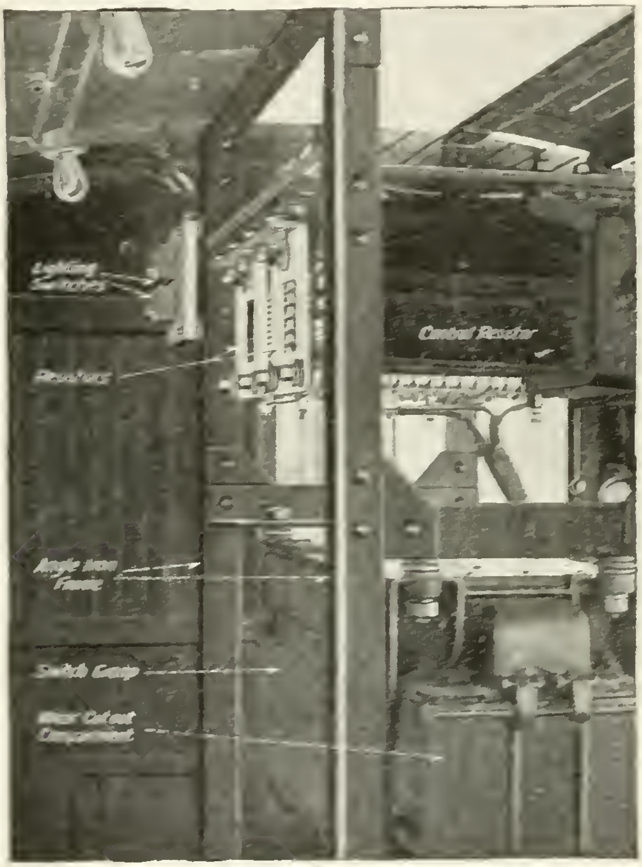


FIG. 6—CENTRAL ARRANGEMENT OF CONTROL APPARATUS OF A STEEL-TYPE LOCOMOTIVE
With protecting screens removed.

MECHANICAL PARTS

The underframing of the locomotive has been accurately termed the "backbone" of the structure. This acts as a support for the cab and the greater portion of the equipment and, at the same time, transmits to the couplers the pulling force developed by the motors. Not only must this structure care for the pulling of trains, but ofttimes it is subjected to severe shock.

In all lines of construction, the use of commercial shapes is preferred wherever possible. In the present case, the longitudinal members of the structure consist of rolled steel channels, while the transverse braces and practically the entire underframing is in the form of shapes built commercially. This renders the structure not only amply strong, but needed repairs can easily be effected in a shop having ordinary facilities. Due to the necessity of operating over city streets and into terminal cities over very sharp curves, the radial draw-bar is in general use on a large number of locomotives. These locomotives are required to operate largely with steam road equipment and for this reason, M. C. B. couplers have come into common usage, placed at a height of 34½ inches above the rails.

Experience has shown that for locomotives up to and including 65 tons, four-wheeled, swivel trucks render excellent service. These trucks are of sufficiently long wheel base to give a satisfactory weight distribution and, at the same time, permit operation on sharp curves and switches, running in either direction. These trucks, of necessity, must be designed to perform the double function of carrying the weight of the locomotive and transmitting to the main frame, the tractive effort developed by the motors. Only in high-speed service, where locomotives are comparatively heavy, has it been found desirable to use articulated trucks. These will give much easier riding at fifty to sixty miles per hour but, at the same time, there is an accompanying increase in complication, which is unnecessary for ordinary electric traction locomotives.

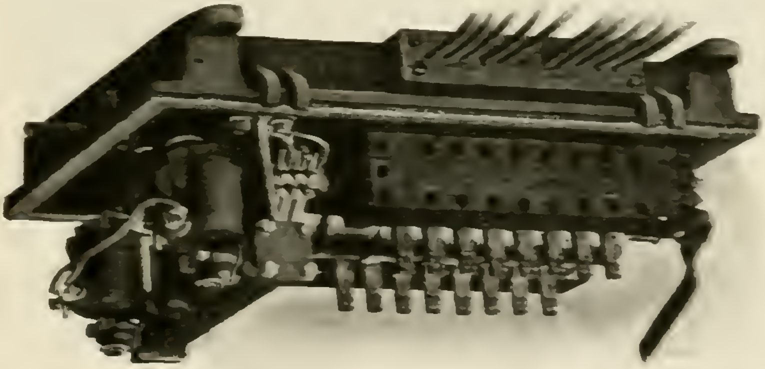


FIG. 7—ELECTRO-PNEUMATICALLY OPERATED REVERSING SWITCH

With the swivel type truck, there is, in addition, the better opportunity for inspection and renewal of wearing parts, a less complicated brake rigging, and it is claimed by many that the articulated truck is far more severe on track and switches than is the swivel type.

The steeple type of cab is made of either wood or steel. The steel cab is far more durable and if the service involves a fire risk, such a cab is absolutely essential. The function of the cab is to protect the engineer and the apparatus from the weather and it must permit sufficient space for the proper installation of the apparatus and afford the operator a good view of the track under all conditions. The steeple type of cab has been used largely on locomotives up to and including 65 tons, but at the present time has not been used extensively for larger locomotives.

LOCOMOTIVES FOR LARGE SYSTEMS

The class of service described on the preceding pages and the type of motor equipment mentioned, are applicable to the ordinary interurban electric railway. In the case of some of the larger systems and new roads or new divisions which are being projected, there is the necessity of long hauls and through service. This type of operation requires motors of somewhat higher speed characteristics than those mentioned previously.

As an example of this, the Southern Pacific Company have resently installed fifteen 60-ton, 600-1 200 and 600-1 500 volt locomotives for their Pacific coast properties, including the Pacific Electric Railway, the Peninsular Railway, the Central Pacific and the Portland, Eugene & Eastern Railway.

The characteristics of these machines are:—

Weight of locomotives complete, approximately 60 tons.
Weight on mechanical parts, 77 250 pounds.
Rating of locomotive one-hour basis with forced ventilation, 1 000 hp.
Weight of electrical parts, 45 250 lbs.
Tractive effort, 30 000 lbs.
Nominal tractive effort at 13.2 miles per hour, 21 600 lbs.
Maximum speed on level track with average load, 25 miles per hour.
Control, pneumatically operated, remote, unit switch.

Track profile	Number of cars each weighing 45 tons with load	Max. speed miles per hour
Straight level track	50	18.4
½ percent grade	26	17.6
1 percent grade	16	17.6
2 percent grade	8	17.6

In addition to freight haulage by interurban railways, there has recently been inaugurated by the Oakland, Antioch & Eastern Railway Company, of California, a type of haulage entirely new on American interurban railways.

High-speed passenger trains to have a balancing speed of 55 to 60 miles per hour, are to be operated from San Francisco to Sacramento. Sleeping cars and chair-car service will be maintained between these two important cities of California, which offer new fields in the operation of interurban railways. In this service 62-ton locomotives are to be used, equipped with field control motors and unit-switch control. Field control is used to secure a large starting or tractive effort at a minimum of current consumption, and further allows high speed running when desired. Articulated trucks are used on these locomotives to care for the very high speed to be maintained.

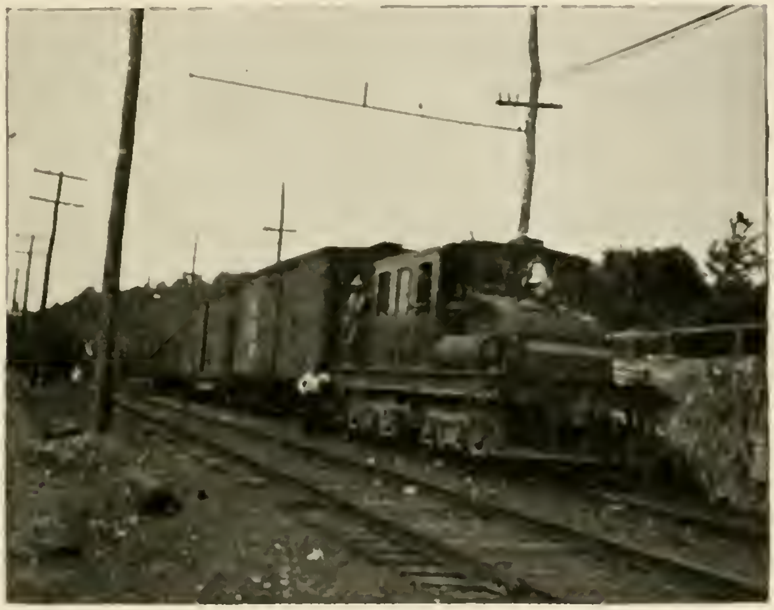


FIG. 8—FORTY-FIVE TON LOCOMOTIVE WITH TRAIN
On the lines of the Connecticut Railway Company

The utility of the electric locomotive in enlarging the range of possibilities on new systems and increasing revenues on existing systems by promoting new types of operation, is a distinct advance. The rapid progress made in recent years is shown by the fact that more electric traction locomotives have been installed during the past two years than in all previous years. The result of this development will unquestionably act to further increase the scope and prestige of the interurban system.

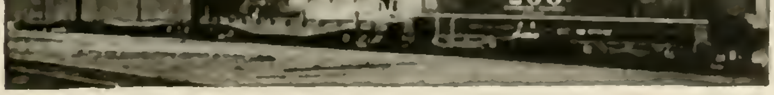


FIG. 9—SIXTY TON FREIGHT LOCOMOTIVE
On the lines of the Southern Pacific Company.

CATENARY LINE CONSTRUCTION ON CURVES

W. SCHAAKE

A VARIETY of methods are employed for holding the trolley wire above the center of the track on curves, each method having some specific advantage for specific operating conditions. In planning overhead construction a careful study should be made to determine which type can be most economically installed and will give greatest reliability in operation.

In the first catenary trolley line in this country the trolley wire was held over the center of the track by means of a steady strain insulator. In this construction an arm made of iron pipe extended from the trolley pole to the trolley wire. The arm was pivoted at the trolley pole so that the end connecting to the steady strain ear might be free to move in a horizontal plane and due to the length of the rod and the flexibility in the joint at the pole some vertical movement was also obtained. Insulation was obtained by means of a porcelain insulator at the pole. This type of construction is shown in Fig. 1. As the distance from the inside of the pole to the center of the track is usually not less than 7 ft. 6 in. for interurban service, the steady strain arm becomes rather heavy and produces a "hard spot" in the trolley line.

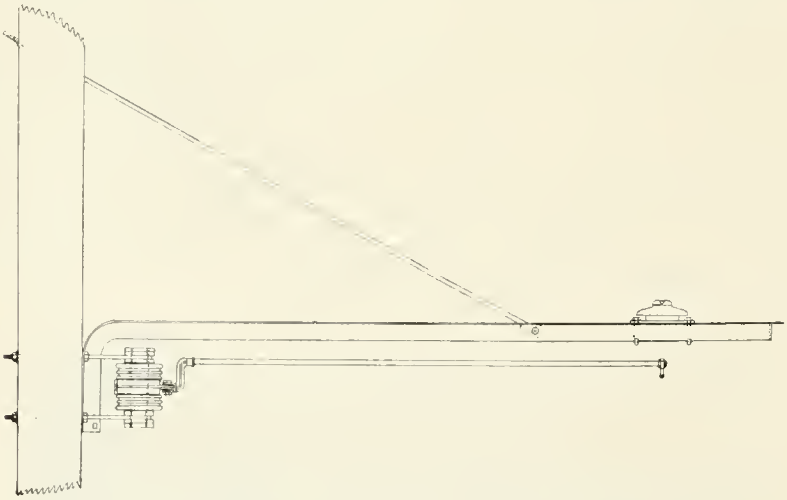


FIG. 1—EARLY FORM OF STEADY STRAIN ARM

This form of construction was superseded by a steady strain insulator pivoted at the bracket arm, as shown in Fig. 2. This results in a much shorter and lighter device and one which is giving good service on a large number of installations. In the most recent types the steady strain end connecting to the trolley ear is free to move in an arc in a vertical and also in a horizontal plane. This tends to partially eliminate the blow of the collector at the steady strain ear and also avoids breaking the steady strain end casting at the bracket arm in case a break occurs in the trolley wire. Insulation is obtained by means of impregnated hickory in the steady

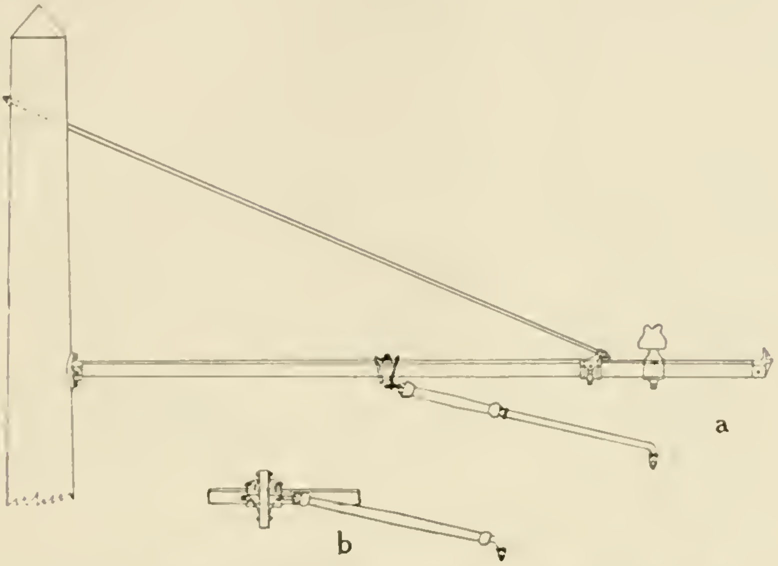


FIG. 2—IMPROVED FORM OF STEADY STRAIN ARM
a—For 6 600 volts or less.
b—For more than 6 600 volts.

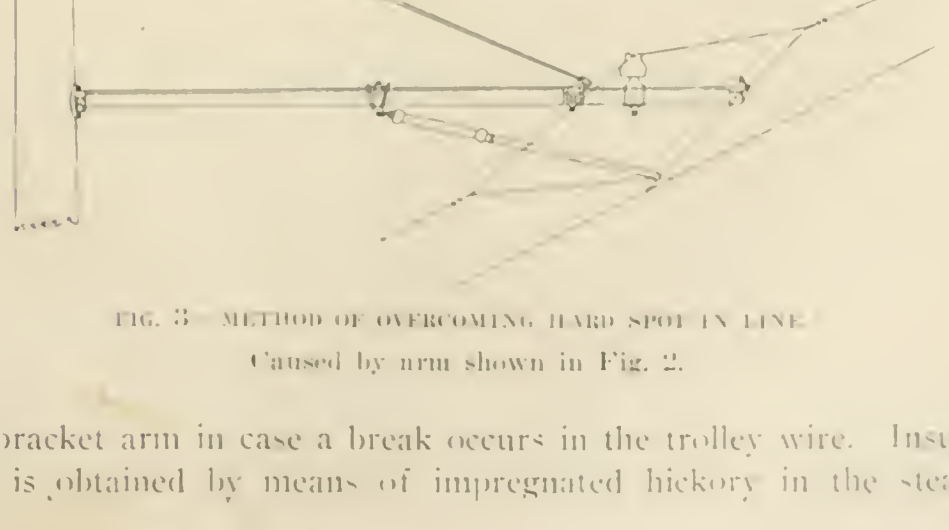


FIG. 3—METHOD OF OVERCOMING HARD SPOT IN LINE
Caused by arm shown in Fig. 2.

strain arm for voltages of 6 600 or less, and by a porcelain insulator in addition to the wood insulator for voltages over 6 600, as shown in Fig. 2 (b).

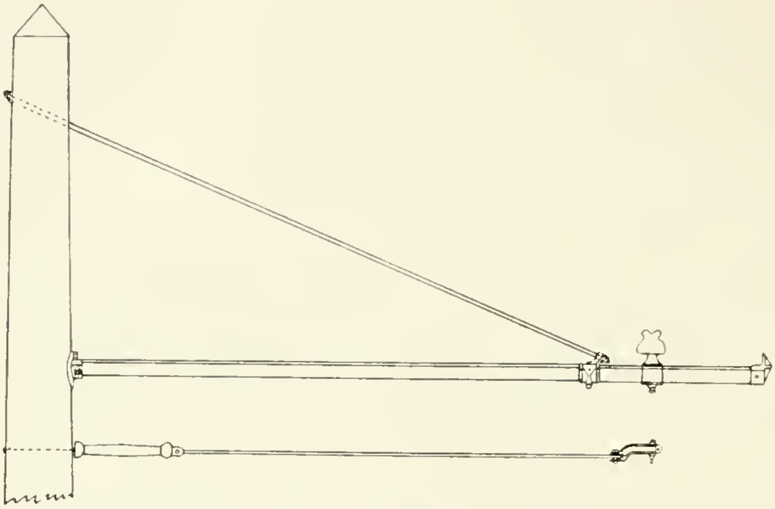


FIG. 4—PULL-OFF FOR USE WHERE POLE IS ON OUTSIDE OF CURVE

Where the poles are on the outside of the curve the steady strain exerts a pull on the trolley wire with a slight tendency to raise the wire till a condition of equilibrium results and the wire is free to respond to the upward pressure of the collector. With the poles on the inside of the curve the steady strain arm exerts a push on the trolley wire. Owing to the angularity of the steady strain with the plane of the trolley wire, one component tends to depress

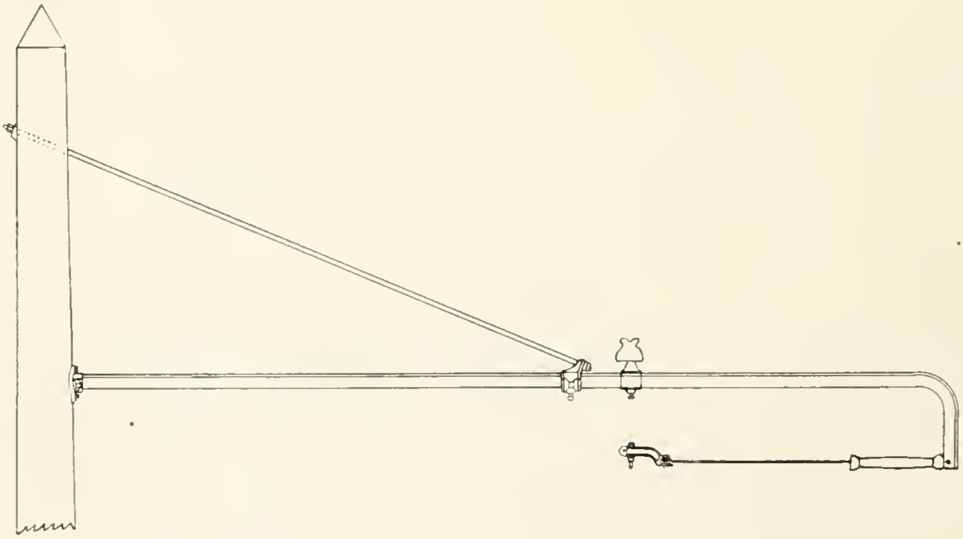


FIG. 5—PULL-OFF FOR USE WHERE POLE IS ON INSIDE OF CURVE

the trolley wire at the steady strain ear, thus producing a hard spot at this point. On curves of long radius the depression may not be marked, as only a small thrust suffices to produce the desired result, but where the radius of curvature is small a decided thrust is required and a marked depression results. This has been a serious objection to this type of steady strain.

A very slight addition can be made, however, which will remove the hard spot in the line, and at the same time give a certain amount of resilience at this point. As shown in Fig. 3, a one-quarter inch cable is attached to the steady strain goose-neck at the steady strain ear. From this point connection is made to the messenger cable. The tension in the steady strain cable is adjusted so that a state of equilibrium will result, with an elimination of the hard spot. The necessary material will consist only of five or six feet of one-quarter inch Bessemer strand, a connection casting at the steady strain ear and two Crosby clips. This same device can be employed where this type of steady strain is used for steadying the trolley on tangent track, in order to remove the weight of the steady strain from the line.

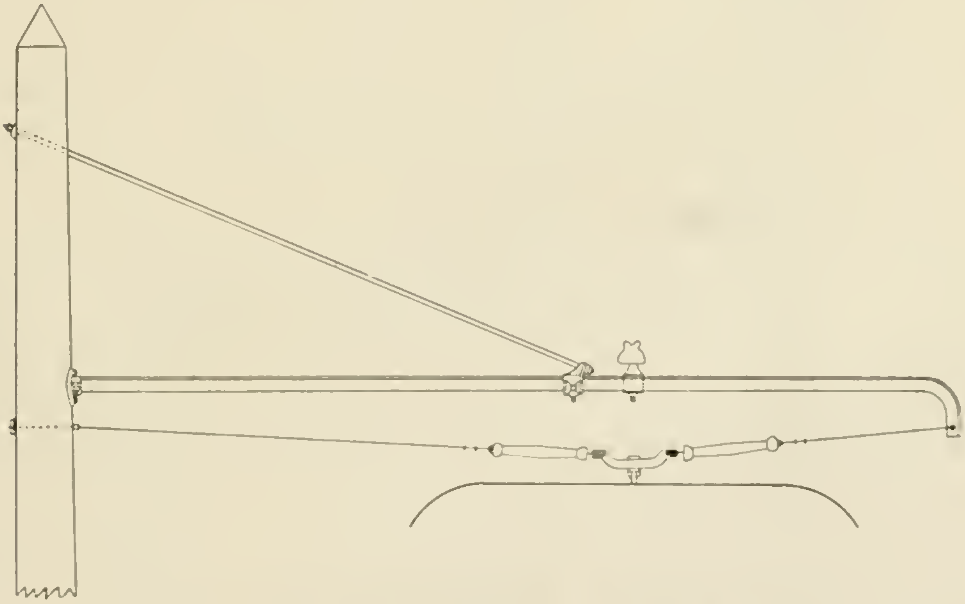
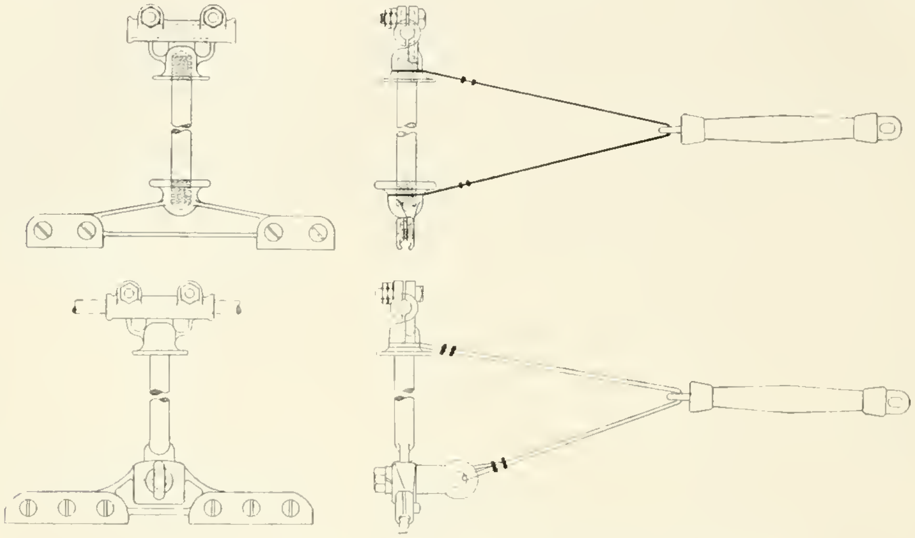


FIG. 6 – PULL-OFF OF TYPE SHOWN IN FIGS. 4 AND 5
Adapted for use with pantagraph trolley.

Some objections have also been raised to the steady strain arm, due to interference with the trolley pole when the trolley wheel leaves the wire. If this were a frequent occurrence, it would seriously interfere with the satisfactory operation of the line and is therefore a point well worth considering. Where used for 600 to 1 500 volts, the steady strain arm consists of an impregnated wood strain insulator with a 12-inch insulation distance and a three-quarter inch steel rod screwed into an end casting at one end and provided with a goose-neck screwing into the steady strain ear at the other end. The eye end casting of the steady strain connects to a U-bolt fastened in the bracket arm clamp, which allows freedom of movement, as already described. For 1 500 to 3 300 volts, an insulation distance of two feet is used and a shorter goose-neck rod. For 3 300 to 6 600 volts, an insulation distance of 48 inches is used and the goose-neck rod is omitted. The steady strain end casting is made in the form of a goose-neck screwing into the steady strain ear. For ease of erection and in adjusting the alignment of the trolley wire, it seems that the type of construction just described is about all that can be desired.



FIGS. 7 AND 8—INTERMEDIATE PULL-OFF HANGERS
For slow speed and high speed service, respectively.

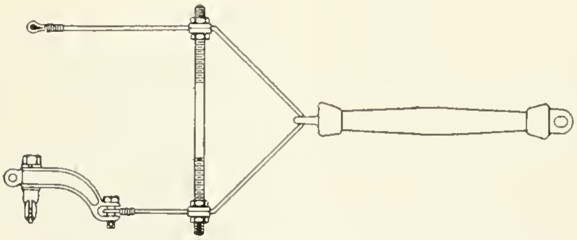


FIG. 9—PULL-OFF YOKE AND SPREADER BAR

In order to obtain greater flexibility and freedom from damage due to interference with the trolley pole when the trolley wheel leaves the wire, a type of construction shown in Fig. 4 is used. With poles on the outside of the curve and for wheel trolley operation, this type of construction becomes very simple, but with poles on the inside of the curve an extension bracket arm is required, as shown in Fig. 5. For use with pantagraph trolleys with sliding or roller collectors, a modification of the construction shown in Figs. 4 and 5 is required in order to avoid interference with the collector. This modification is shown in Fig. 6, and consists of a double curve yoke used in conjunction with wood strain insulators and an extension bracket arm.

For wheel trolley operation, on curves having a radius shorter than one degree, pull-off hangers are required at intermediate points in the span in addition to steady strains at the bracket arm. For slow-speed operation or infrequent service, a pull-off hanger of the type shown in Fig 7 may be used, while if greater flexibility is desired a hanger like that shown in Fig. 8 should be used. The trolley ear in this hanger is pivoted to the hanger rod so that relative movement of the messenger and trolley wire will not kink the trolley wire. There is also less tendency for the collector to strike a blow at the end of the ear than in a more rigid type of hanger.

FIG. 10—CONSTRUCTION SHOWN IN FIG. 9
Adapted for use with pantagraph trolley.

Another type of construction which has proven very satisfactory is shown in Fig. 9. In this type of construction a standard single curve pull-off yoke is used in conjunction with a spreader bar having clamps and nuts which allow a certain amount of adjustment, so that the direction of pull of the messenger and trolley pull-offs will be in a horizontal direction. Flexibility at the point of pull off is obtained and there is little liability of damage due to a trolley wheel leaving the wire. For use with pantagraph trolley, a modification must be made, as shown in Fig. 10, in order to avoid interference with the collector.

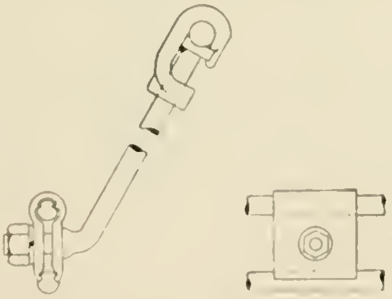


FIG. 11—PULL-OFF HANGER
For curves of radius greater than four degrees.

A type of construction which has proven very satisfactory for curves of radius greater than four degrees is shown in Fig. 11.

No bridle wire is required with this type of construction, as the trolley wires are pulled over the center of the track by the side pull of the messenger cable. The trolley wire assumes a curve almost coinciding with the center of the truck. The hangers are spaced on ten-foot centers and every hanger becomes a pull-off hanger. The hangers for a 150-foot span weigh about 1.25 pounds each and, as the trolleys are supported at one side of the messenger in a state of equilibrium, the whole structure has great flexibility and is eminently adapted for high-speed operation. With the hangers connected directly to the messenger cable, no additional insulation is required for curves This is an especially important feature when a high voltage line is considered, and when elimination of strain insulators greatly adds to the reliability and simplicity of construction. For curves having a radius shorter than four degrees and with the double trolley type of construction, pull-off cables such as shown in Fig. 12 become necessary.

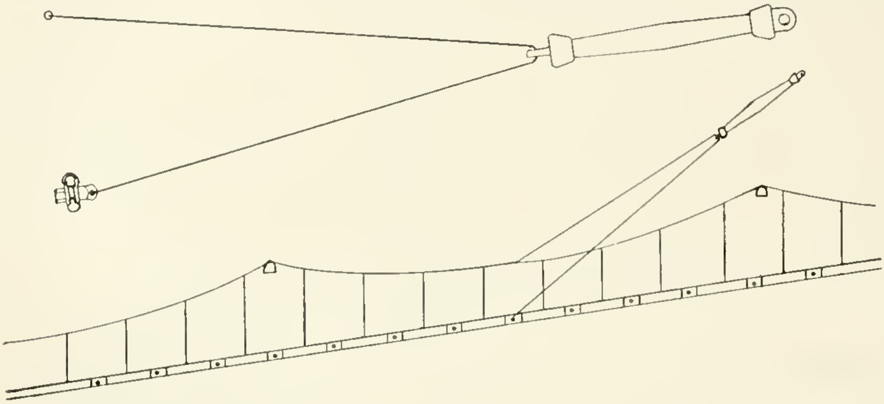


FIG. 12—PULL-OFF FOR DOUBLE TROLLEY
For curves having a radius shorter than four degrees.

GRID RESISTORS FOR RAILWAY SERVICE

A. H. CANDEE

THE EXACTING SERVICE required of electric railway equipments demands that all parts be designed and built to withstand very severe mechanical and electrical conditions. This is especially true of the resistors which are used during starting and accelerating the motors, and in order to meet these requirements the grid type of resistor is now generally used where it is practical to do so.

A great deal of care has been taken in the design of standard grids in order to give them the maximum mechanical strength, and at the same time to make them capable of withstanding sudden and severe temperature changes without undue strains and without breakage. Resistors are usually mounted underneath the car and are exposed to ever-changing weather conditions. The temperature of the grids in cold weather may change as much as 300 or 400 degrees C. within a short time, due to excessive overloads, yet the grids are designed to stand this without breaking. Vibration in passing over rough track also imposes severe strains on the grids. One of a standard line of grids which is used in assembling resistors for railway service is shown in Fig. 1.

TABLE I—CHARACTERISTICS OF STANDARD EIGHT INCH RESISTANCE GRIDS

Approx. Cross-Section—Sq. In.	Approx. Length of Conductor—In.	Resistance in Ohms	Amperes Capacity*
0.0475**	189	0.2	27.3
0.0510	171	0.1	38.7
0.0633	171	0.08	43.3
0.0625	153	0.07	46.3
0.0775	153	0.06	50.0
0.0810	135	0.05	54.8
0.1005	135	0.04	67.2
0.1290	116	0.03	70.8
0.1360	96	0.02	86.5
0.1600	96	0.015	100.0

*Continuous capacity with 240 degrees C. rise in temperature.

**Cast of special iron alloy to give additional strength.

The grids are cast in this general form from a tough, freely flowing iron, but in order to obtain the various ohmic resistances required, it is necesary to vary the cross-section of the iron. The allowable rate of heat dissipation being approximately the same for all cross-sections of the same size of the grid, it is evident that as the cross-section decreases the resistance increases and thus the current carrying capacity of the grid is decreased. The grids of the smaller cross-sections, however, are sufficiently sturdy to withstand the rigors of railway service. The characteristics of standard eighth-inch resistance grids for three-point suspension are shown in Table I.

Great care should be exercised in the electrical design of a resistor for railway service, inasmuch as a faulty design will cause a great deal of trouble. To go into the actual detail design of the resistor would require a lengthy discussion and only the main points to be considered are given here. As a general rule, for car service, the total ohmic resistance in the circuit on the starting notch should be sufficient to limit the starting tractive effort to a value somewhere between 120 and 140 pounds per ton of car weight. The total resistance, therefore, is a function of the number and capacity of motors, trolley voltage, gear ratio, wheel diameter, car weight and type of controller. Smooth acceleration must be provided for by properly proportioning the various resistance steps. The current carrying capacity required for each step must then be determined. After the determination of the total resistance, proportioning of the steps and capacities required for the steps, it is only necessary to pick out suitable grids, decide the correct number per step, and build them up into one or more frames according to the best arrangement. A frame for three-point suspension consists of three mica-insulated tie rods upon which the grids are mounted, the tie rods being supported at the ends by sheet iron end plates, and the grids insulated from the end plates by mica washers. Suitable electrical connections are made between grids by inserting copper instead of mica washers between the mounting bosses of adjacent grids. The grids are then clamped between the end frames by nuts on the ends of the tie rods and held in place by lock washers. This construction, shown in Fig. 2, gives rigidity to the frame.

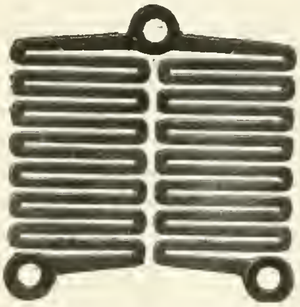


FIG I—GRID USED IN THE ASSEMBLING OF RESISTORS

In general, there is no fixed rule with regard to the method of resistor mounting, but several electric railway companies have adopted the practice of hanging two wooden beams from the car body by heavey iron straps, the resistance frames then being supported from these beams. The bolts which support the individual frames are placed in holes drilled and countersunk in the wooden beams so that the bolt heads are approximately half an inch below the surface of the beam, and are then sealed in by an insulating compound poured in while hot. This method thoroughly insulates the end frames and reduces failures due to grounding of resistors, for, although the grids themselves are insulated from the end frames, snow, water or mud on the top of the resistor might short-circuit from the grids to the frame. Over the whole resistor is mounted a sheet of asbestos lumber with holes drilled for bringing the cables through; also the exposed portions of the beams are covered with asbestos. The leads which are brought through the upper sheet of asbestos are stripped of insulation and, after being bent to the exact shape desired, the strands are soldered together.

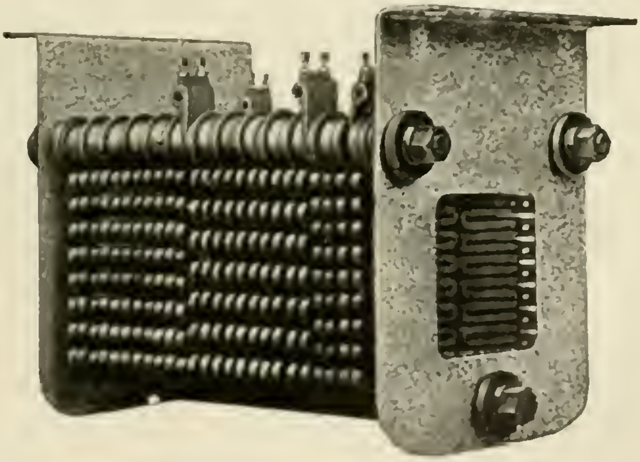


FIG. 2—COMPLETE RESISTOR SHOWING METHOD OF MOUNTING GRIDS TO OBTAIN RIGIDITY

The location of the grid resistor under the car depends largely upon the arrangement of the other apparatus. It should be placed so as to secure the best possible ventilation and at the same time should be protected from wheel wash.

A number of electric railways have attempted to standardize their grid resistors. Unless all of the cars of a system are very nearly the same, this is practically impossible, since the resistance will vary with the type and numbers of motors, trolley voltage, gear ratio, wheel diameter, car weight and type of controller. It is sometimes possible to standardize individual frames to some extent, but even in this case something must usually be sacrificed either in weight, capacity or smooth acceleration.

RAILWAY TYPE LIGHTNING ARRESTERS

T. A. McDOWELL

LIGHTNING arresters for railway service, prior to the introduction of the electrolytic type of arresters, had for a long time been confined commercially to three general types, which are still in use. Now, however, the electrolytic arrester, for station service, has become recognized as standard, but for car mounting its use is new and as yet very much restricted. In the older types of arresters, practically no recent changes in design have been made, except in the form of container or in other minor respects.

A form of arrester which has given much satisfaction both for car mounting and pole mounting, under all ordinary conditions, is illustrated in Figs. 1 and 2. This arrester is of the smallest and most compact design of any so far developed, which makes it easily protected from all conditions of weather and dirt when mounted under the car, without requiring excessive space. The arrester which consists of a spark gap in series with a carborundum block, is entirely automatic in its operation without the use of any moving parts; it, therefore, requires no attention after installation, except inspection at long intervals to see that it is in proper condition.

The principle of operation of this arrester is based upon the ability of the carborundum block to break down and offer great freedom of discharge at abnormal voltages, yet to offer a very high resistance at normal voltage. This block is not a resistor in the ordinary sense, but is so constructed as to provide a very large number of minute gaps between the conducting particles of carborundum. These gaps break down freely at voltages which would be dangerous to the insulation of railway apparatus, and under such conditions the absence, in this arrester, of the usual series resistor provides for a much greater freedom of discharge than would otherwise be possible. When normal voltage is restored it is impossible for the arc to be continued across these many gaps, and the dynamic circuit is therefore broken. Arresters of this type eventually require replacement owing to the disintegration of the carborundum blocks after a certain number of discharges, but in ordinary service they will last for seven to ten years, and replacements can be made economically owing to the comparatively low cost of this design.

Arresters operating on the principle of the straight series airgap and resistor, with arrangements made to discharge the dynamic are by either a magnetic blowout or a series connected circuit breaker, have been in use for so long as to be well understood.

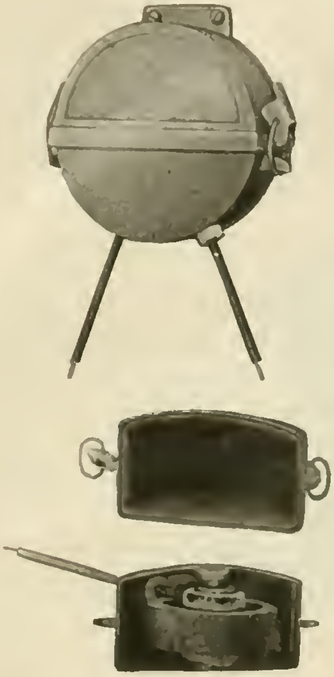


FIG. 1—EXTERIOR AND INTERIOR OF LIGHTNING ARRESTER FOR RAILWAY SERVICE

For the protection of apparatus in the direct-current generating station, the smaller arresters ordinarily used for car and pole mounting are not adequate when the value and importance of the apparatus is considered. The old idea of a direct connection to ground through a water resistance has generally been discontinued in favor of apparatus of later design, and for the reason that such protection is not obtained until after the connection is especially made for each lightning storm. The failure of the station operator to make the connection, for any reason, would subject all apparatus in the station to possible damage.

With the advent of the electrolytic arrester for alternating-current service, a design for direct-current railway service was also developed and the protection offered is relatively high, just as in the comparison of electrolytic arresters with other and older types of alternating-current arresters. Owing to the very small leakage current through an electrolytic arrester on direct current, these arresters are arranged to be permanently connected without any spark gap, and therefore are kept in operating condition without the periodic charging necessary in alternating-current arresters. Attention need not be given to these arresters, usually, oftener than once a year. The protection offered justifies any additional trouble represented by this type, as compared with any other which has so far been offered for this service. An electrolytic station arrester of exceptionally rugged design and great freedom of discharge is illustrated in Fig. 3.

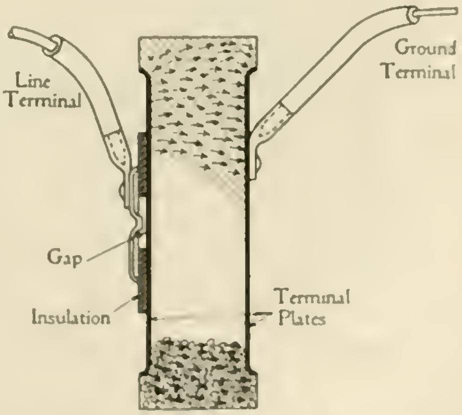


FIG. 2—CROSS-SECTION OF ARRESTER SHOWN IN FIG. 1 INDICATING DIRECTION OF CURRENT FLOW DURING DISCHARGE

For 1 500 volt railway work, commercial arresters for pole mounting have been confined to the spark gap and resistor type, with magnetic blowout or circuit breaker attachment, and little attempt was made at first to mount arresters on the cars. These designs have proven more or less inadequate for proper protection and, owing to the increasing use of high voltages in direct-current railway work, various developments are under way which will no doubt provide arresters that will give adequate protection and which may be mounted either on the cars or poles.

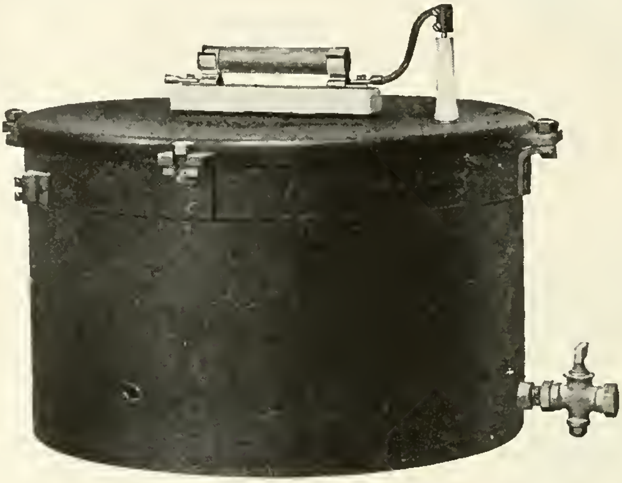


FIG. 3—ELECTROLYTIC LIGHTNING ARRESTER FOR RAILWAY SERVICE.

For ordinary 600 volt service, the use of the electrolytic arresters for car mounting has been confined to a few cases only, due to the high initial cost and greater inconvenience connected with the upkeep of this apparatus as compared with the older designs. Their use is apparently justified only in those cases where the lightning conditions are so severe that the ordinary forms of protection are inadequate.

SHOP TESTING OF ELECTRICAL APPARATUS—X

SINGLE-PHASE RAILWAYS MOTORS

THE SERIES MOTOR of the resistance lead type may be designed for either alternating-current, or both alternating and direct-current operation. In the former, the compensating field winding is short-circuited upon itself and excited by transformer action, which has the advantage of reducing the voltage strain between winding and ground to a minimum. In the latter the compensating field winding is in series with the armature circuit The testing methods for the two machines are identical when operating on alternating current. For direct-current operation the tests are similar to those for direct-current railway motors and usually consist of a commercial test and heat run.

All illustrations, numerical and curve data given in connection with the tests in this article were taken from the test of a 275 volt, 25-cycle, single-phase railway motor of 175 brake horse-power capacity at a one hour, 75 degrees C. rating.

RESISTANCE

The resistances to be measured in this case are those of the armature, compensating field and series field windings. In measuring the armature resistance, at least four readings, taken at different positions on the commutator necks, should be used to get a good average value. The readings for this test were taken at a room temperature of 20 degrees C. and are given in Table I together with values corrected to 25 degrees C.

TABLE I—RESISTANCES

	At 20° C	At 25° C
Armature	0.01111 ohms	0.01131 ohms
Series field	0.002805 ohms	0.00286 ohms
Compensating field	0.003549 ohms	0.00362 ohms

Temperature coefficient for 20 degrees C = 1.0197.

SPEED TEST

This test is taken by coupling the motor to another motor of such a capacity, when operating as a generator, as to be able to carry 150 percent load on the motor to be tested. The second motor is loaded by connecting it to a resistance rack or water rheostat and run as a direct-current machine. A booster is con nected in the load circuit, as shown in Fig. 1. The load is then controlled by adjusting the field of the booster which makes possible very close regulation. The voltage of the power supply for this test should be under the control of the tester by the use of field control or by means of an intervening regulator.

Speed readings are taken in each direction of rotation as a check on the neutral position of the brushes, and they should check within 5 percent of each other and of the rated speed of the motor. To conduct this test the motor is first run in one direction for a period of about one-half hour to secure a good brush contact on the commutator. The speed curve is then taken for that direction of rotation. Similarly the brushes are worn in and the curve taken for the other direction. Readings of line volts, line amperes, line watts, field volts and watts, armature volts, frequency and speed should be taken at the 50, 75, 100, 125 and 150 percent values of load for each direction of rotation. A complete set of readings for this test is given in Table II and the corresponding curves are plotted in Fig. 2.

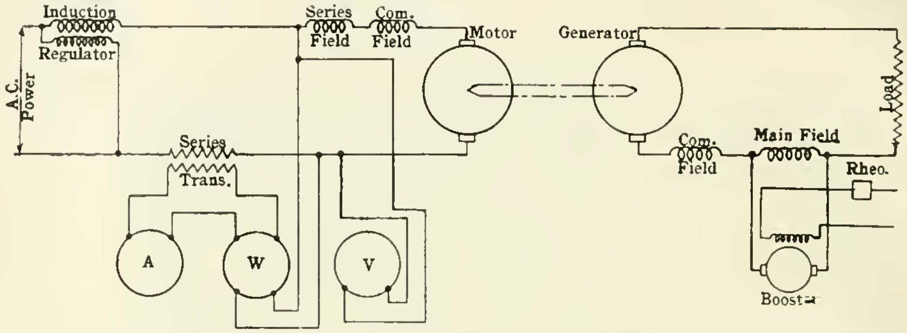


FIG. 1—DIAGRAM OF CONNECTIONS FOR LOADING A SERIES SINGLE-PHASE RAILWAY MOTOR

TABLE II—25 CYCLE SPEED CURVE

Line			Field		Arm. Plus Comp. Fld.	
Amperes	Volts	Kw.	Volts	Kw.	Volts	R.P.M.
			Counter-Clockwise Rotation			
350	275	89.6	88	2.56	249	958
503	275	121.8	108.5	4.59	235	730
700	275	158	127.5	7.07	219	569
900	275	192	141.0	10.4	203	465
1100	275	216	152	14.64	186	379
			Clockwise Rotation			
1100	275	233	152	14.83	198	420
900	275	201	140.5	10.5	214.5	503
700	275	166	126	6.86	229	605
503	275	126	108.5	4.25	243	776
350	275	92.8	89	2.59	253	991

BRAKE TEST

Accurate results can be obtained on a brake test only by the exercise of extreme care. Accordingly all constants, such as length of brake arm and the tare of the brake, should be carefully measured and the brake well balanced before starting. Tare is determined by suspending the brake on a knife edge at the point where a vertical line through the center of the shaft intersects the brake arm, the other end resting on the scales, care being taken that all accessories used on the scales during the test be included in the tare weight.

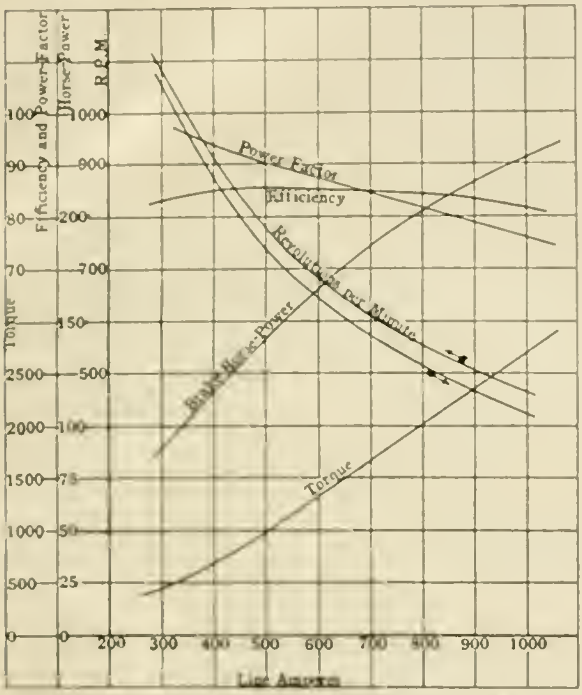


FIG. 2—PERFORMANCE CURVES OF A SERIES SINGLE-PHASE RAILWAY MOTOR

The motor should be started on low voltage to check the direction of rotation; if it is correct, the voltage is gradually increased to normal, with a gradual increase in the brake load. The operation of the brake should be carefully observed as the load is being applied. The brake rubbing surface should be well greased, run smoothly, and be properly supplied with cooling water. After starting to take readings, no changes should be made in the conditions of the test other than adjustments to keep the load constant

TABLE III—TORQUE TEST BY BRAKE

Line			Field		Arm Plus Comp. Fld.		Torque*
Amp's	Volts	Kw.	Volts	Kw.	Volts	R.P.M.	Ft.Lbs.
1040	200	109.2	147	11.67	81	139	2800
920	200	106	141	9.62	105	192	2400
804	200	102.4	131	8.15	116	246	2000
692	200	97.2	125	6.48	132	308	1600
565	200	86.4	114	4.85	145	402	1200
432	200	72	101	3.35	159	524	800

Length of brake arm—48 inches. Tare—47 lbs.
*Tare deducted.

Readings of line amperes, volts and watts, field volts and watts, armature volts, speed and scale readings are taken for six or seven points covering the range of operation of the motor. The peripheral speed of the brake pulley should not in any case exceed 5 000 feet per minute. The terminal voltage should be held constant at the rated value throughout the test, if possible. However, if the speeds are too high the test may be taken at a lower constant voltage, as in the accompanying example.* Complete data for this test are given in Table III and the resultant horse-power and torque curves are plotted, as indicated in Fig. 2.

TABLE IV—CORE LOSS TEST READINGS

BRUSHES DOWN

Driving Motor			Tested Motor				
Volts	Amps.	Watts	Field Amps.	Field Volts	Kw.	Armature Volts	R. P. M.
48	49.85	2395	0	0	0	0	406
48	108.5	5210	1100	151	13.72	190	405
55	57.5	3162	0	0	0	0	485
55	106.5	5855	900	141	9.65	206	485
65	68.5	4750	0	0	0	0	585
65	105	6830	700	127	6.75	230	587
81	72	5840	0	0	0	0	753
81	103	8350	500	110	4.31	250	750
103	72	7420	0	0	0	0	970
103	92.2	9500	350	91	2.74	268	973

BRUSHES UP

Driving Motor			Tested Motor			
Volts	Amps.	Watts	Field Amps.	Field Volts	Kw.	R. P. M.
46	15.9	731	0	0	0	405
46	76	3500	1100	151	10.45	408
52	17.1	890	0	0	0	487
52	69	3590	900	141	7.61	483
63	19.2	1210	0	0	0	582
63	61	3840	700	127	5.2	586
76	22.85	1745	0	0	0	751
76	54¼	4110	500	110	3.26	755
98	25.75	2520	0	0	0	970
98	48	4710	350	91	2.06	972

DRIVING MOTOR, BELT OFF

Armature Amperes, I	Armature Volts, E	Watts Input, IXE
8.7	101.0	880
7.8	75.5	590
7.4	64.0	474
7.2	57.5	414
6.9	52.0	359

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*For a given motor current, the torque is practically independent of the voltage.

CORE LOSS AND SATURATION

In taking this test the motor is belted to a small direct-current motor in the manner described for direct-current generators,* and the main motor field is excited with alternating current, the armature circuit remaining open. The direct-current supply circuit should contain a booster capable of varying the voltage over a wide range. The losses measured are rotational losses, primary or transformer losses, friction and windage and brush friction.

TABLE V—PRIMARY LOSSES

Amperes	300	400	500	800	1000
I^2R armature	1214	2160	3380	8650	13500
Short-circuit kw	600	800	1020	1780	2600
Primary core loss	1500	1930	2420	4220	5560
I^2R brush	550	844	1195	2580	3780
I^2R main field	307	545	853	2180	3410
I^2R comp. field	388	692	1079	2762	4320
Total primary loss	4559	6971	9947	22172	33170
Primary loss volts	15.19	17.42	19.87	27.6	33.17

The rotational losses include the core loss, caused by rotation through the magnetic field, copper loss in cross-connections of cross-connected armatures, copper and other losses in armature coils and armature leads which are short-circuited by the brushes, as far as these losses are due to rotation. These losses are measured by the driving motor.

The primary or transformer loss includes core loss due to the reversals of the alternating-current field, copper loss in the cross-connections of cross-connected armatures, copper and other losses in the armature coils and leads which are short-circuited by the brushes, as far as these losses are due to the alternations of the magnetic flux. These losses are measured by a wattmeter in the field at the same time the rotational losses are found.

TABLE VI—PERFORMANCE DATA

Amperes	300	400	500	800	1000
Terminal volts	275	275	275	275	275
Total energy volts	269.7	257.8	248	225	209
Primary loss volts	15.2	17.4	19.9	27.6	33.2
Counter e. m. f.	254.5	240.4	228.1	197.4	175.8
R.P.M	1090	890	752	535	413
Rotational loss volts	32.6	21.5	15.7	7.1	5.1
Output volts	221.9	218.9	212.4	190.0	170.7
Brake horse-power	89.0	117.3	142.4	203.8	229.0
Torque	438	693	995	1999	2719
Power-factor	98.0	93.6	90.2	81.9	76.0
Efficiency	82.2	84.9	85.7	84.5	81.6

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* See the JOURNAL for May, 1913, p. 460.

Readings for both the rotational and the transformer losses are taken simultaneously, and cover a range from 150 percent field current to the lowest value within the safe limits of speed. Starting at the maximum value of field current, readings of line amperes and line volts on the driving motor; and field amperes, field volts, field watts, armature volts and speed on the machine being tested are taken at each point. For each value of excitation the corresponding speed is obtained from the speed curve, Fig. 2, and the driving motor is adjusted accordingly by varying the armature voltage. If the speeds in the two directions of rotation differ, as determined by the speed regulation test, their average values should be used for this test. The alternating-current field is then removed and the set held to the same speed by adjusting the field of the driving motor, whose voltage should be held to the same value as before removing the alternating field, in order to keep its losses approximately constant. In other words, two sets of readings are taken at each value of speed, one with and one without the alternating-current field, the driving motor voltage being held constant for both.

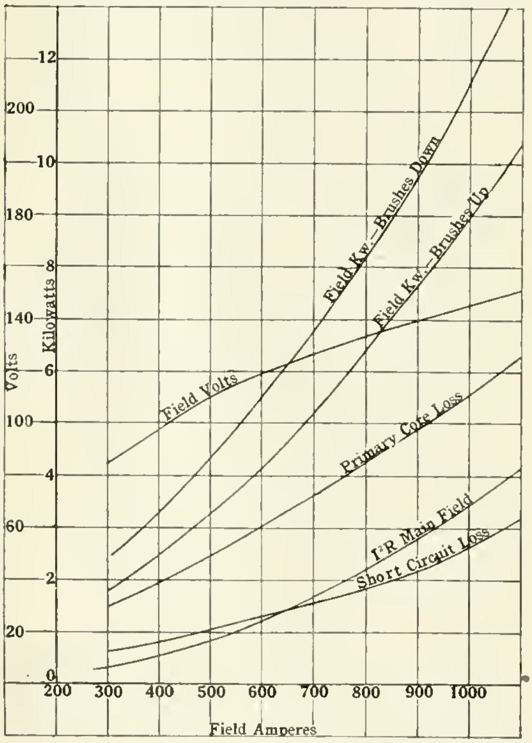

FIG. 3—CURVES OF PRIMARY OR TRANSFORMER LOSSES

The entire test is then repeated with brushes lifted on the tested machine, the same readings being taken with the exception of that of armature volts, which is necessarily omitted. On completion of this test the belt is removed and readings of terminal volts and amperes input to the driving motor are taken over the same range of voltage. A complete set of readings as taken for this test together with derived values of watts on the direct-current machine is given in Table IV.

From this data two sets of curves are plotted, the one for primary losses and the other for rotational losses. In determining primary losses, curves of field kilowatts, with brushes up and brushes down, I²R loss in the field, and field volts are plotted against field amperes as common abscissæ, as in Fig. 3. Then the difference between the curves of kilowatts with brushes up and with brushes down at each point equals the loss in the coil short-circuited by the brushes, and the difference between the curves of I²R loss in the field and kilowatts with brushes up, equals the primary or transformer core loss in the field and armature due to the reversals of the magnetic flux. These two curves are also plotted in Fig. 3.

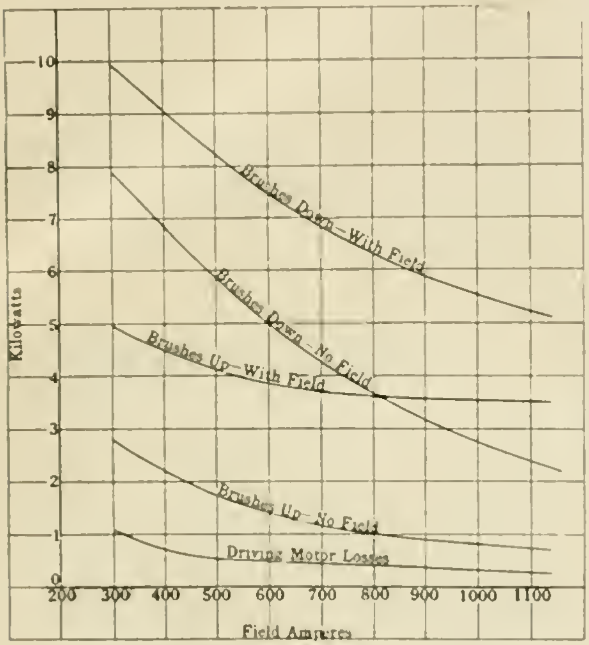

FIG. 4—TEST CURVES PLOTTED FROM ROTATIONAL LOSS DATA GIVEN IN TABLE IV

For the rotational losses, curves of kilowatts input to the driving motor are plotted with field on the tested machine, both with the brushes up and with the brushes down; also with no field on the tested machine, with the brushes up and with the brushes down. These curves together with a curve of kilowatts input to the driving motor, with the belt off, are plotted as in Fig. 4. The core loss, due to the rotation of the armature, will equal the difference between the curves with brushes down, with and without field excitation; and also the difference between the curves with brushes up, with and without field excitation. These two values should be the same, but in the average test there will be a slight difference. Therefore, the mean value should be used for

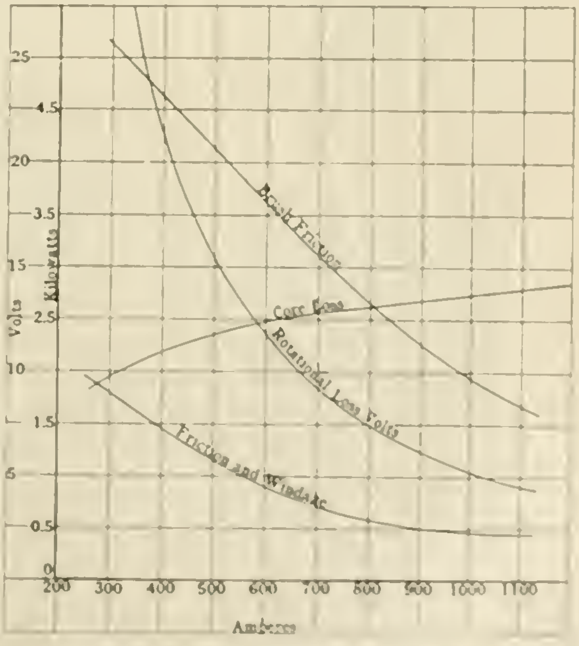

FIG. 5 ROTATIONAL LOSS CURVES DERIVED FROM FIG. 4 FOR USE IN CALCULATING EFFICIENCY

the real core loss. The brush friction equals the difference between the readings with brushes down and brushes up, without field. The friction and windage equals the difference between the kilowatts with the brushes up, and no field and the driving motor losses. These curves, together with the values of rotational losses in volts (which equals rotational losses in watts at each point divided by the current, are plotted at the corresponding values of field amperes in Fig. 5.

EFFICIENCY

The following data obtained from the test outlined above is used in the computing of efficiency :—

(1) Rotational losses = Rotational core loss, friction and windage, brush friction.
(2) Primary losses = Copper loss in the armature series and compensating fields, brush I^2R, short-circuit loss and primary core loss.
(3) Rotational loss volts = Rotational losses in watts divided by current.
(4) Primary loss volts = Primary loss in watts divided by current.
(5) Total energy volts = Watts from Table II divided by current.
(6) Counter e. m. f. = (5)--(4).
(7) Output volts = (6)—(3).
(8) Brake horsepower $= \dfrac{\text{Output volts} \times \text{current.}}{746}$
(9) R. P. M. = From speed curve.
(10) Torque—Ft. Lbs. $= \dfrac{\text{Brake Hp} \times 5250.}{\text{R. P. M.}}$
(11) Efficiency $= \dfrac{\text{Output volts}}{\text{Total energy volts.}}$
(12) Power factor $= \dfrac{\text{Total energy volts.}}{\text{Terminal volts}}$

Resistance of armature at 25 degrees	0.01131.
Resistance of armature at 75 degrees	0.0135.
Series field at 25 degrees	0.002858.
Series field at 75 degrees	0.00341.
Compensating field at 25 degrees	0.00362.
Compensating field at 75 degrees	0.00432.

Total Brush Area=18 square inches.

A complete tabulation of primary losses in watts with the corresponding reduction to voltage values, as indicated in (4) above, is given in Table V, and complete performance data for this motor at the same ampere values is given in Table VI. As the motor is series wound, the line ampere values against which these curves are plotted are identical with the field ampere values for the previous curves. From this data curves of power-factor and efficiency are plotted with the curves of brake horse-power, torque and speed, as in Fig. 2.

TEMPERATURE TESTS

Railway motors are rated in amperes, volts and time, and in taking a temperature test the motor's guaranteed rating in these quantities is the basis of the test. The machines should be set at least six inches above the floor to allow for ventilation and if the run is continuous, it is common practice to leave the commutator covers on, whereas for runs of one hour they are removed.

The motor is connected up as in Fig. 1 and adjusted to the rated values of current and voltage. The time for which the motor is designed to operate under these conditions is the length of the run. During the test, readings of line volts, amperes and watts, field watts and volts, and speed are taken and the commutation noted Running temperatures of main and compensating fields, front and rear, if possible, frame and laminations are also taken, and hot resistances should be taken on all windings as soon as possible after shutting down, as the machine cools off very rapidly. Temperatures of the commutator on the outside edge, middle and groove, armature copper and banding wire are taken in addition to the running temperatures.

The motor is then uncoupled from the generator and the over-speed and over-potential tests taken, in the manner described for direct-current railway motors.* Both of these tests should be taken when the motor is at a temperature of at least 90 degrees C. For single-phase railway motors an average value for the over-potential test is 3 600 volts for one minute.

COMMERCIAL TESTING

After measuring resistances in commercial testing, the motor is connected as in Fig. 1. For motors of less than 150 horse-power capacity readings of line volts, line amperes, field volts, frequency and speed are taken at the 75 and 125 percent load points and the commutation is noted. When the compensating field is in series with the armature, the total resistance is measured and compared with the sum of the individual resistances, as a check on the connections. These readings form a sufficient check on the motor as compared to the limits of operation allowed by its guarantee. It is then subjected to the regular over-speed and over-potential tests.

On motors larger than 150 horse-power, the readings specified above are taken at four points instead of two, namely, at 50, 75, 100 and 150 percent load. The remainder of the test is the same as for smaller machines

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*See the JOURNAL for Sept., 1913, p. 807.

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967—Power-Factor Correction:—I have a 200 k.v.a., three-phase, 60 cycle, 220 volt generator, 480 amperes per phase, running on a purely inductive balanced load of 70 k.w with full load current of 500 amperes per phase. This gives about 37 percent power-factor. I have also a 30 k.v.a., three-phase, 60 cycle, 220 volt generator, 72 amperes per phase that I wish to run as a synchronous condenser. (a) What correction will such an outfit make on the above power-factor, while it is itself delivering about three horse-power? (b) What kind of a starting compensator would be necessary?

I. F. (PENNA.)

(1) The current rating per phase of the 200 k.v.a. generator mentioned should be 526 amperes; similarly, the 30 k.v.a. machine should have about 79 amperes per phase. Assuming, however, 500 and 72 amperes for the two machines respectively, as stated, and allowing for the probable no load losses of the smaller machine in addition to the three horse-power of outside work it is to furnish, the resulting power-factor should be about 46 percent. In this connection it should be borne in mind that it is not safe to assume that this machine will carry full rated current at zero power factor, without excessive heating of the field winding, especially if the machine is of old design. (2) The starting characteristics of the machine cannot be estimated, even approximately, without more complete information regarding the winding and bracing of the machine, and particularly whether or not it has dampers, for without the latter it might not start at all from rest even with full voltage applied, and even if started it might not lock into synchronism. It might be well to try starting the machine when no other load is on the larger generator, by applying 50 or 60 percent voltage on the machine through some temporary transformer arrangement, observing very carefully any movement of the coils when the current is first turned on. If there appears to be no mechanical shock to the windings, full voltage might be tried, and if the machine will not start from rest, it may do so when it has been given a few turns by hand. Care should be taken not to allow the current to remain on for more than a few seconds, in case the machine does not start, as otherwise, a burnout is likely to occur.

N. S.

968—Starting Rotary Condensors:—We have in our plant a synchronous motor which we are using as a rotory condenser. We start this motor as follows: The field switch is opened and the motor started with a compensator, running on the starting side until the motor gets up to speed when the field switch is closed. (The exciter is connected to the motor shaft and meantime has built up its voltage.) Then after the ammeters steady down the compensator is thrown into the running position. Is there any better way of starting without the aid of a small starting motor? What would be the result of leaving the field switch in when starting and allowing the fields to build up with the exciter voltage? Would it strain the insulation of field coils any more than the present method? The field switch does not split up the field as now wired. L. A. F. (MASS.)

It is standard practice either to start synchronous condensers with the motor field directly connected to a direct-connected exciter armature or with the motor field short-circuited (if separate exciter is used), both methods relieving the strain on the motor field insulation due to the high induced e.m.f. (split fields not being common on synchronous motors). N. S.

969—In a certain text book I find a formula for determining the power factor from the readings of to wattmeters, as follows:

$$\text{Power-Factor} = \tfrac{1}{2}\sqrt{\frac{(1+X)^3}{1+X^3}}, \text{ where } X = \frac{W_1}{W_2}$$

Please explain its derivation and use.

J. G. K. (QUEBEC)

The above formula is correct. The fundamental formulae are:

$$W_1 = E\ I \cos\ (\theta + 30^\circ) \text{ and}$$
$$W_2 = E\ I \cos\ (\theta - 30^\circ),$$

where W_2 is the reading of the wattmeter giving the larger indication, and W_1 the one giving the smaller indication on a lagging power-factor. When the currents in the phases are balanced (and this method is only applicable when this condition is true), the terms EI are equal. Dividing one equation by the other and substituting the value

$$X = \frac{W_1}{W_2},\ X = \frac{\text{Cos}\ (\theta + 30^\circ)}{\text{Cos}\ (\theta - 30^\circ)}$$

Solving this equation for cos θ, the equation as given in the question is obtained. A more convenient form of the same equation is:

$$\text{Power-factor} = \frac{1+X}{2\sqrt{1-X+X^2}}.$$ Still another equation, involving the actual wattmeter readings instead of their ratio is:

$$\text{Power-factor} = \frac{1}{\sqrt{1+3\left(\frac{W_1-W_2}{W_1+W_2}\right)^2}}$$

See also article by Mr. H. N. Lucas in the JOURNAL for September, 1912, p. 761. C. R. R.

970—Testing Transformers Without Oil:—Is it necessary to put the oil in a large transformer of the oil cooled type in order to supply the voltage it is connected for; in other words, is it safe to test the transformers at rated voltage without oil, provided no current is flowing which would would cause heating of the coil. "A" claims that the oil serves only to transmit the heat from the windings to the water cooling coils and that while it assists the insulation of the coils, nevertheless, the coil insulation is sufficient to withstand the voltage without the presence of the oil. "B" claims that the presence of the oil is necessary to prevent a break-down of the transformer insulation at normal voltage. Which is right? H. E. W. (UTAH)

If transformer is of comparatively low voltage, say around 11 000 volts, it will probably be safe to apply normal voltage without the oil in the tank. For high voltages, however, the tank must be filled with oil before applying the voltage, as the oil is required as much for insulation purposes as for conveying the heat to the cooling coils. The insulation is not strong enough without the assistance of the oil.

W. M. M.

971—Alternators Coupled for Parallel Operation:—Two alternating-current generators are to be coupled by flange couplings to the same prime mover and are to operate in parallel. In order to obtain the proper relation of one rotor to the other would it be correct to parallel the stators with an ammeter in each phase and with the rotors at rest and pass alternating current through the rotor winding? One rotor may then be shifted with respect to the other until zero current is noted in all three stator ammeters, which would be the proper angular relation of one rotor to the other. A practical application would be where two generators are to be connected to one high speed hydraulic turbine, the flange couplings being drilled at the installation. Manifestly the scheme proposed would not work when both rotors are to be pressed to the same shaft. R. W. C. (MASS.)

The method suggested may be feasible but will not be very accurate. Since the field set up by the alternating-current in the field winding will be single-phase, the voltage in corresponding phases of the two machines will vary in amount and not in phase with different relative positions of the rotors. For this reason slight differences in position will cause only slight differences in voltage. This method might be useful as a first approximation, the final relationship being determined by the usual method of running the machine at no load. F. D. N.

972—Rotary Converter Operation:—(a) When one of three delta connected transformers, connected to a rotary converter, burns out, how can I put out the fire and cool off the transformer; and how can I connect up the other two transformers so that the converter can be used in case of emergency. (b) When the potential transformers burn out or get out of order, how can I synchronize the rotary converters? (c) When the starting transformer burns out how can I start up the rotary converter to get it up to speed for synchronizing? P. W. B. (NEW YORK)

(a) If station is supplied from a high power transmission line and no protective devices are between incoming line and transformers, there is a possibility that an arc started in a transformer will tend to burst it and the flying oil cause a fire. By providing proper protective devices, however, there is no likelihood of the trouble extending beyond the transformer case. If one of the transformers breaks down it may be disconnected and the converter run from the two remaining transformers without changing connections to them. (b) Synchronize with a bank of lamps connected across the alternating-current switch. (c) Start by any one of the following methods: 1—From the direct-current side if suitable power is available. 2—Insert resistance in the alternating-current side. to lower the applied voltage. 3—Reduce voltage of the alternating-current generator supplying the rotaries, by means of the generator's exciter. R. H. N.

973—Rotary Converter Switchgear:—Why has it been the custom in the past to always place field-reversing and field-splitting switches on the machine? Why not on the switchboard, thus having everything under the operator's immediate control? P. F. A. (AUSTRALIA)

It has been customary to place the field-reversing and break-up switch on the frame of the rotary converter on account of the large number of leads between the field winding and the switch. There is no other reason why it should not be placed on the switchboard panel and this location would, undoubtedly, be more convenient in certain stations. F. D. N.

974—Testing Enameled Wire:—Please tell me briefly what simple tests can be taken on enameled wire in order to pass an opinion as to the quality of the covering, etc. R. D. C. (OHIO)

Wire which will withstand the following tests is usually considered good. The enamel should not be soft enough to be scratched with the finger nail. The wire should stand bending around a radius of approximately two and one-half times its own diameter, and should stand an elongation of 30 percent without cracking the enamel. When a layer is wound on a mandrel one-half inch in diameter, the enamel should withstand voltages between the wire and the mandrel, of 500 to 1 000 volts, depending upon the size of the wire. When a length of ten feet of wire is immersed in mercury, the enamel should withstand a voltage of 100 to 250 volts, between the wire and the mercury, depending upon the size of the wire. R. W. E. M.

AMERICAN ELECTRIC RAILWAY ASSOCIATION ANNUAL CONVENTION

The 32nd annual convention of the American Electric Railway Association will be held in Atlantic City, October 13-17.

The principal items in the program of the American Association and the Engineering Association are:

Monday, 2 P. M.—Annual address and reports of committees on standards, Power Distribution and Electrolysis.

Tuesday, 2 P. M.—Reports of Committees on Block Signals, Train Operation—City and Interurban.

Tuesday, 2 P. M.—Reports of Committees on Subjects, Company and Individual Membership, Education. Addresses on "Valuation," by Mr. Frank Berger and Mr. C. M. Rosecrantz.

Wednesday, 9:30 A.M.—Reports of Committees on Buildings and Structures, Heavy Electric Traction and Power Generation.

Wednesday, 2 P. M.—Reports of Committees on Insurance, Public Relations, Aero Advisory—Welfare of Employes, Electrolysis, Company Sections, Gold Medal, Constitution and By-Laws, Relations with Sectional Associations. Addresses—"Profit-Sharing with Employees," by Mr. W. F. Ham, vice-president, Washington Railway & Electric Company, and Mr. D. W. Ross, vice-president, Interborough Rapid Transit Company. Address, "The Relations of Carriers to the Development of the Territory they Serve," by Mr. Paul Shoup, president, Pacific Electric Railway Company, Los Angeles. Address, "The Relief of City Congestion by the Constitution of Subways and Viaducts," by Mr. C. S. Sergeant, vice-president, Boston Elevated Railway Company.

Thursday, 9:30 A. M.—Reports of Committees on Engineering Accounting. Addresses on "Engineering Accounting and Life of Railway Physical Property."

Thursday, 2 P. M.—Reports of Committees on Compensation for carrying U. S. mails, taxation matters, federal relations, joint use of poles, cost of passenger transportation service. Addresses on "Electric Railway Securities from the Investors' Viewpoint," by Mr. C. W. Beall of Harris, Forbes & Company, and by Mr. F. E. Frothingham, of Perry, Coffin & Barr; on "Present Tendency of Public Utility Laws and Regulations," by Mr. Frank Hedley, vice-president, Interborough Rapid Transit Company, Mr. C. L. S. Tingley, vice-president, American Railways Company of Philadelphia, and Mr. Richard McCullock, vice-president, United Railways Company of St. Louis.

Friday, 9:30 A. M.—Reports of Committees on Equipment, Standards and Education.

An unusual effort has been made to get the executives as well as the operating officials to attend this convention. Additional meeting room space has been provided and an unusually large exhibit of manufacturers' apparatus is planned.

PERSONALS

Mr. H. S. Block has been appointed manager of works of the Westinghouse Lamp Company, Bloomfield, N. J., to succeed Mr. R. H. Henderson, who resigns to take up other work. Mr. Block has had long experience in this line of work with the National Quality Lamp Division of the General Electric Company. For the last three years he has been in charge of their St. Louis factory.

Mr. F. B. H. Paine, general manager of the Niagara Lockport & Ontario Power Company has severed his connection with the company.

Mr. Henry D. Jackson, consulting engineer, 88 Broad Street, Boston, is on a three months' vacation trip in Bermuda. He expects to return about January 1st.

Mr. W. B. Miser, until recently of the Chicago district office of the Westinghouse Electric & Mfg. Company, has been appointed manager of the Jacksonville (Ill.) Railway & Light Company.

Mr. G. W. Borst, for the past three years with the engineering department of the Western Electric Company, has accepted the position of chief electrical engineer of the Chicago Fuse Mfg. Company. Prior to his association with the Western Electric Company, Mr. Borst was with the Westinghouse Company in Pittsburgh.

Mr. D. W. Smith, formerly of the industrial and power sales department of the Westinghouse Electric & Mfg. Company, has been appointed manager of motor sales of the Robbins & Meyer Company, Springfield, Ohio.

NEW BOOKS

"An Expensive Experiment"—Reginald P. Bolton. 281 pages, illustrated. Published by The Baker & Taylor Co. Price $2.00.

This book has to do with the extensive transmission system constructed by the Hydro-Electric Commission of Ontario, Canada. It treats only of the financial phase and aspects of this unusual governmental development. The undertaking represents one of the largest public ownership institutions supplying light and power on this continent, and consequently has attracted wide-spread attention. The operation of such a system represents a new departure and naturally the control of such large properties by political authorities is beset with difficulties and often with economic deficiencies. Discrimination between communities, various classes of service and industries is shown to exist by the author. The reported results of operation are misleading, as in the expenses are omitted, sinking fund, depreciation and provision for adequate maintenance. By taking all elements of cost into account it is proven that the prices obtaining in certain localities before the system was established were lower than the cost at which the commission may properly distribute hydro-electric power. The burden falls upon certain classes of consumers and the tax-payers of the province. That it reflects upon the financial credit of the province has already become apparent. This book may be studied by the utility companies and the economist with profit.

E.D.D.

"Rules of Management"—William Lodge. 139 pages. Published by the McGraw-Hill Book Co. Price, $2.00.

The author, who has been for years president of the Lodge & Shipley Tool Company, gives in this little book an actual instance of how certain things were done. There are no generalities. In his experience he had certain conditions in his shop. He wished to let younger hands take on the active direction of the work of his Company and, as a means of seeing that his policies were carried out by his successors, he wrote out certain rules and methods, in plain straight-forward language, taking up in turn various divisions of the work coming under such headings as, the general manager, the chief engineer, the drawing room, the purchasing agent, the superintendent of manufacturing, the chief clerk, the cost and time keeping department, the operation of the premium plan, the pattern shop, the tool making room, the forge department, the lathe department, the grinding department, the drilling department, the planer department, the milling department, the gear cutting department, instructions for painting lathes, the sales manager, the shipping clerk, the engineer, electrician and oil man, janitors and watchmen, the proposed pension plan. The first chapter, devoted to "the exceptional employee," contains some excellent advice. The book is characterized by its intimate personal tone in reviewing the requisites of men for the various positions.

"Transformer Practice"—William T. Taylor. 278 pages, 191 illustrations. Published by the McGraw-Hill Book Co. Price, $2.50.

In going over this second edition of this book, one is impressed by the apparent wandering habits of the author, the first edition being dated in India and the second in Peru. The book is intended particularly for those who are operating or constructing plants containing transformers. Much of the information contained in the book is based on results of the experience of the author in various parts of the world covering a number of years. The first 116 pages, are devoted to transformer combinations and difficulties. A chapter is devoted to the construction, insulation and operation of large transformers, also to methods of cooling transformers. A good sized chapter is devoted to transformer testing in practice with a concluding chapter on transformer specifications.

"Steam," Its Generation and Use. Published by the Babcock and Wilcox Company.

This 35th edition of this well-known book is a large volume of 335 pages handsomely printed and illustrated. In general the arrangement is similar to previous editions, but there is much that is new both in the text and illustrations. Among the new illustrations of installations are full page photographs of the Woolworth Bldg., McAlpin Hotel, and Bankers Trust Bldg. While the book is ostensibly a company publication, there is so much of engineering value in it that it forms an excellent text-book on steam practice and data.

THE
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Meeting the Tariff Reduction

Efficiency engineering has played a most important part in the electrification of manufacturing establishments in every industry. Factory managers everywhere, who have been alive to the necessity of reducing their manufacturing costs while improving the quality of their product, have turned to electric drive as the solution of their problem, and the results have fully proved the wisdom of their course.

The new tariff bill invites increased foreign competition in nearly every industry, and, therefore, reduced profits to the manufacturer. This means that a reduction in the cost of manufacture is not only necessary to insure the continuation of profitable business in numerous instances, but in many others is required to perpetuate the very life of the plants themselves. The advantages derived from motor drive are, therefore, of special interest at this time to those engaged in every industry, as well as to those whose time is devoted to the various phases of the electrical business.

Along with other commodities, sugar is to be placed on the free list. About one hundred years ago the first refined beet-root sugar was produced at a cost of approximately eighty cents per pound. Today one can purchase at retail about fifteen times this quantity for the same amount of money. During this period many improvements have occurred, which cover the entire field of effort of sugar production, from the cultivation of the raw material to the handling of the finished product; but still more improvements are necessary and the further equipment of refineries with motor drive will play an important part in bringing this about.

The article in this issue of the JOURNAL by Mr. Wirt S. Scott, relative to the production of beet sugar, is of especial interest at this time, as this is one of the industries which has been hit hardest in the recent revision of the tariff schedules. This article not only describes in an interesting manner the process of manufacture, but points out very clearly the saving which can be made where motor drive is utilized, notwithstanding the fact that this is an industry in which steam plays an important part for other than power purposes.

H. W. COPE

Recent Improvements in Tungsten Lamps

Dr. Lederer's paper on "The Tungsten Lamp and Its Development," published in the present issue of the Journal, presents an interesting resume of the history of the incandescent lamp in general and the metallic filament lamp in particular. Reading between the lines, one can readily appreciate the enormous amount of research work which was necessary to bring the tungsten lamp to its present high state of efficiency in such a comparatively short time. And the end is not yet, as it is still at the present time in an active process of development.

Recent improvements in the tungsten lamp bear in the main on the question of obtaining greater efficiency without a corresponding decrease in the candle-power maintenance during the life of the lamp. This has been accomplished by introducing into the lamp small amounts of chemical substances which prevent the blackening due to particles of tungsten thrown off from the incandescent filament. The useful life of the lamp on the user's circuit therefore approximates much more closely than formerly to the actual life which the filament would give if the blackening had not appeared on the bulb. Not only has the chemical introduced into the lamp been instrumental in preventing the blackening, but it has also made it possible to decrease the size of the bulb in several types of lamps, notably the 60 watt lamp, with the corresponding possibility of adapting them to a much wider variety of uses.

A further improvement has been made by constructing new tungsten lamps in which the filament is concentrated within a smaller radius than that of the ordinary types. This could hardly have been accomplished with the former brittle filaments, but the introduction of the drawn wire with its characteristics of great pliability and ductility has made it possible to coil the wire into helical springs which have sufficient elasticity so that their various convolutions do not touch each other when burning. Thus, it has been possible to get nearer to the so-called point source of light, and especially improve the construction of automobile headlight and other types of lamps where such an arrangement of the filament is particularly desirable. A further advantage of the concentrated filament arrangement resides in the fact that lamps constructed in this manner are considerably stronger mechanically than the older types of lamps with their great length of straight filaments.

A further improvement of possibly far reaching importance has lately been introduced by the use of an atmosphere of inert gases, principally nitrogen, in the tungsten lamp. While lamps constructed in this manner have hardly passed the experimental stage, yet the indications are that they can be burned at a considerably higher efficiency than ordinary lamps, even as low as one-half watt per candle. It is possible therefore that when lamps of this type become fully developed they may effect the art of incandescent lighting to an extent that can only be surmised at present.

It is therefore obvious from the foregoing remarks that a great deal yet remains to be done in the development of the incandescent lamp and that it still presents a very fruitful field for experiment and research.

G. P. Scholl

Circuit Breaker Ratings

Mr. Mahoney makes a timely suggestion in his article on "Circuit Breaker Ratings" which appears in this issue of the Journal. Up to the present time it has been customary to rate a circuit breaker in terms of the aggregate capacity of synchronous apparatus installed in close proximity thereto. Instead of that method, Mr. Mahoney suggests a method of rating which depends upon the actual kilovolt-amperes which the circuit breaker will interrupt successfully, as determined by multiplying the normal voltage of the circuit by the maximum amperes which the circuit breaker can be depended upon to interrupt successfully.

We consider that such a modification in method of rating circuit breakers is highly desirable. The old method, which depended solely upon the amount of synchronous apparatus in close proximity, could, of course, take no cognizance of the differing character of that synchronous apparatus, nor could it recognize the existence of current limiting reactances. Both of these features have a tremendous effect upon the amount of current which a given circuit breaker may be called upon to interrupt, and, consequently, are of vital importance in so far as the rating of circuit breakers is concerned.

By proper use of the current limiting reactances, the amount of current which a circuit breaker will be called upon to interrupt on a given system may be cut down tremendously. The usual method of installing reactances in generator circuits, of course, cuts down the short-circuit current of a group of generators to a considerable extent. However, the more logical method of installing current limiting reactances in feeder circuits will serve to cut down the short-circuit currents to a tremendously larger extent. When dealing with the question of circuit breakers, the matter of reactances in feeder circuits as against generator circuits becomes a very important item in determining the ultimate cost of switching apparatus.

We believe that this question, which is raised by Mr. Mahoney's contribution, is a matter upon which the Standards Committee of the American Institute of Electrical Engineers could properly take official action.

P. M. Lincoln

The Letter To Urban

One who is about to move into a strange country and to live among new people gladly listens to those who can tell, from their own experience, the peculiarities of the country and the characteristics of the people among whom he is to abide. He welcomes suggestions which may aid him in accommodating himself to the new conditions and in getting along smoothly with his new neighbors, and greatly appreciates hints which may assist in successfully accomplishing the particular purpose or work he may have in view. Likewise, the young man entering upon his life work is usually eager to listen to accounts of equipment and methods and organization and men, and he is especially intent when the story of the rise of the inventor or sales manager or the president is related.

But when one is advised as to his own habits and conduct, and the importance of various personal and moral qualities are dwelt upon, he is apt to lose interest and pass it by as very good for other people, but quite superfluous for personal use. And yet the things which limit most men and hold them back from the front rank are usually personal or moral. Colonel Prout has said, "It is my constant observation of four engineering works, employing about 20 000 men, that engineers reach the limit of their usefulness from defects of character, rather than from want of technical attainments. Our greatest difficulty is to find courage, candor, imagination, large vision and high ambition."

The wise young man who looks forward with large vision and high ambition will welcome the opportunity to share with Urban the counsel his father gives, in the article by Mr. Walter V. Turner appearing in this issue. "Advice is cheap," and that is all that much of it is worth. But the letter written to Urban gives advice that cost a lifetime of effort, and its precepts were dearly paid for in the school of experience.

Very complicated engineering problems are often found, when properly analyzed, to rest upon a very few simple, fundamental principles. Very able and successful men are often found, when their methods and characteristics are analyzed, to have accomplished their results by simple and commonplace means, just such simple and for the most part obvious rules of conduct as are set forth by Mr. Turner.

The representative of a large manufacturing company in addressing the senior class of an engineering school last Spring said, "My company wants leaders, and I come here to find whether any of you men have nerve enough to undertake to become its leaders twenty years from now." Then he told some of the experiences which were involved and some of the traits which would be essential. It seems to me that the young man who is starting for the top may study to good advantage the rounds of the ladder by which the chief engineer of the foremost air brake company in the world attained his position.

Chas. F. Scott

Central Station Power In Coal Mines

Mining as an industry has made wonderful strides in the last decade. But it is one of the few industries wherein the methods of production have not kept pace with the demand for the product. Only in recent years have the operators realized that they were not giving this phase of their business the attention it warranted.

The constantly increasing demand for coal to supply the immense manufacturing plants and railroads, tended to increase competition, a condition which permits of no material increase in the selling price. On the other hand the cost of production has increased. Therefore, although the gross returns have been higher each year, the net profits have been falling off. Naturally, the coal operators are looking for ways and means to increase their net earnings.

The cost of power construction is a very material part of the gross expense of mining coal. To many people it seems like "carrying coals to Newcastle" for a coal company to purchase its electric power. True, at first glance, it appears ridiculous that a power company could sell at a profit a commodity manufactured from the principal product of the customer. But, as Mr. Rickards says in his article in this issue of the Journal, making power is a business in itself. In the first place, power companies, primarily equipped for supplying lighting and traction loads, already exist in the immediate territory of the mines, and their power equipment, representing an immense investment, is doing little of its intended work during those hours of the day when the mining load is highest.

The coal operator, with his comparatively small and inefficient plant, must be equipped to handle his maximum demand for power, thus tying up a large sum of money to take care of an infrequently occurring peak. On the other hand the central station has the advantage of the "diversity factor"—that is, the fact that its load is made up of various industries, operating under greatly varied conditions, and as a result the central station peak is not so exaggerated, compared with the average load. Even if the day load consisted entirely of coal mines, it is improbable that the individual peak loads would occur on more than 20 percent of the mines at any one time This means a proportionally smaller investment. The central station plant is also made up of larger units, making for higher efficiency, and its employees are experts in their line, thus bringing about economies and reliability of service that the mine man is unable to consider.

Granting that the mine owner can usually purchase power cheaper per kilowatt-hour than he can make it, his profit does not stop here. The purchase of power makes the mine owner watchful over his power consuming equipment and leads to uncovering many wastes that otherwise would pass unnoticed. But, when the power is generated at the mine the cost of power is very apt to be lost sight of and the possibilities of economy never come to light.

Over and above the question of saving in cost is the guarantee of continuous service, and the elimination of the worry and care of running a power business on the side. The mine owner is free to give all of his attention to the mining and shipping of coal, which, after all, is the business he knows best, and is primarily what he depends on for profit.

The use of central station power by mines has been seriously considered only in the last few years, but wonderful results have already been obtained. The points made by Mr. Rickards are all well known to users of central station power and should be carefully considered by every mine operator before installing new power generating equipment. F. J. Foley

BREAKING CAPACITY RATING OF OIL CIRCUIT BREAKERS

APPLICATION TO OPERATING CONDITIONS

J. N. MAHONEY

ONE of the essential requirements of an oil circuit breaker is that it have sufficient circuit-breaking capacity to meet the conditions and the character of the service at the point where it is applied.* The breaking capacity rating of an oil circuit breaker is usually stated at the present time in terms of "ultimate breaking capacity," expressed as the total normal rated capacity of the generating and synchronous apparatus connected to the circuit, which the circuit breaker can be depended upon to successfully control under given conditions. In the ultimate breaking capacity rating of circuit breakers, they are considered as connected directly to, and close to the source of power, and these ratings are based on automatic instantaneous over-load tripping in connection with generators having some specified percentage of inherent reactance, and having the maximum rated voltage given for the circuit breakers. Any departure from these assumptions will change the relative rating.

All reactances added by lines, transformers or otherwise, will increase the breaking capacity rating in direct proportion; for example, if the reactance added by a step-up transformer, a line to a substation and a step-down transformer, be equal to that of the generator capacity, the breaking capacity rating of the circuit breaker in the substation on the above basis will be doubled. When a circuit breaker is to be placed in the secondary circuit of a transformer, the kilovolt-ampere capacity of which is, say, 25 percent or less of the capacity of the generating station, the reactance of this transformer and its capacity are the factors to be considered in determining the breaking capacity rating of the circuit breaker to be applied.

Since the inherent reactance of slow speed generators is usually higher than that of turbo-generators, the breaking capacity rating of the circuit breaker, on the above basis, opening circuits supplied by such generators, would be increased in direct proportion to the increase in reactance of the generators, which is not always true.

Generators of different types have widely varying short-circuit characteristics and inherent reactances. The maximum current flow on the initial wave of short circuit varies from five to fifty times the mean full-load current. The rate of decrease from this initial maximum to the "sustained" short-circuit current varies so that some machines have but one-fourth of this initial maximum at the end of one-tenth second, while others have approximately one-half of the maximum at the end of this same time, and in still other cases, as high as three-fourths of the initial maximum. The final or "sustained" short-circuit current at the end of two seconds varies from approximately one and one-half to three times full-load current. The inherent reactance of circuits, including overhead lines, transforming apparatus or underground cables, may be of almost any value, and this value may be a controlling factor in the short-circuit current that will reach the circuit breaker and the open-circuit voltage that may be caused by the operation of the circuit breaker under overload conditions.

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*This was touched upon by the writer in the JOURNAL for August, 1913.

The method of tripping the circuit breaker is a factor in the current that may exist at the time of opening of the contacts, inasmuch as this opening of the contacts may occur as early as one-tenth of a second after the appearance of the overload, or any greater period, determined by the method of tripping or form of tripping relay used. When the circuit breaker is non-automatic, this time is wholly within the control of the operator, but it is practically a physical impossibility for him to operate it within less than two seconds after the appearance of an unexpected over--load. The operating mechanisms of different forms of circuit breakers are more or less sluggish in responding to the requirements of the different forms of tripping mechanism, so that time periods up to one-half second have been noted from the time the short circuit or overload appeared until the mechanism had separated the contacts in the oil sufficiently to rupture the current flow in an instantaneous automatic circuit breaker.

To cite examples of the speed of operation, it may be said that circuit breakers tripped directly by series trip coils or trip coils directly fed from series transformers and acting directly on the actuating mechanism, will act on short circuit in approximately two to two and one-half cycles on 25 cycles, or approximately one-tenth of a second, especially when the mechanism is equipped with means for accelerating it at a rate greater than the action of gravity. Circuit breakers tripped by what is known as a shunt-trip coil, which is supplied in some cases with direct current through relays, which are in turn acted upon by coils in series with the load current, or which is supplied with current direct from series transformers, take a much greater time to act. This time will vary in length with the form of relay used, with the inertia of the tripping mechanism, and with the form of magnetic circuit used in the trip magnet. The writer's experience is that the least time in which one of these combinations act is approximately one-quarter of a second or six cycles of a 25-cycle circuit, and may be almost any period greater than that, determined wholly by the type of actuating mechanism and method of automatic tripping. This is illustrated by the oscillograms in Figs. 1 and 2, Fig. 1 representing the action of an instantaneous trip relay, and Fig. 2 that of an instantaneous direct trip circuit breaker.

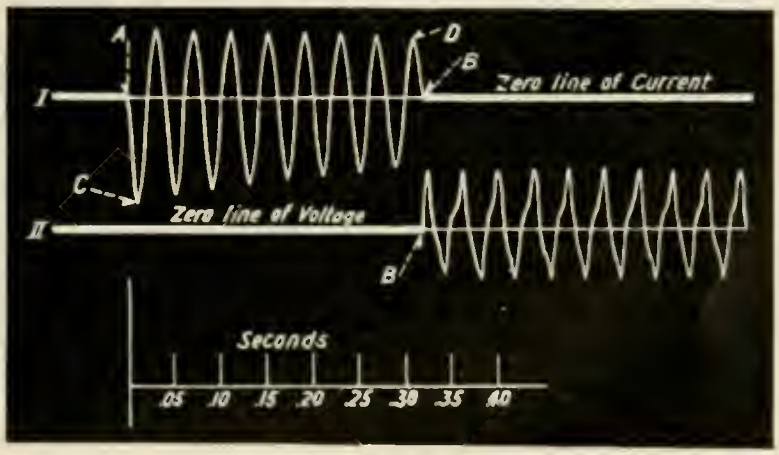

FIG. 1—DIRECT SHORT-CIRCUIT ON ONE-PHASE OF A 30 000 KILOWATT, THREE-PHASE, 25 CYCLE, 12 000 VOLT CIRCUIT, THROUGH A CIRCUIT BREAKER EQUIPPED WITH AN INSTANTANEOUS TRIP RELAY, WITH DIRECT-CURRENT SHUNT TRIP MAGNET

It took eight cycles (about 0.32 seconds) for the circuit breaker to trip, during which time the current decreased from the maximum amplitude, at *C*, to that indicated at *D*. At *B* the voltage rose from zero, during the short-circuit, to the normal generator value, with very little, if any, irregularity.

In a system of considerable size it may be noted that with considerable reactance, provided either artificially or naturally, by means of the lines and transformers in circuit between the generating apparatus and the circuit breaker, short-circuit currents may be constant regardless of the method of tripping, and may be relatively small, compared with the short-circuit currents with the circuit breaker situated near the bus-bars at the generating plant. When the circuit breaker has considerable reactance between it and the source of power supply, the method of tripping or speed of operation would not affect the current it would be compelled to break, and the characteristics of the generators would not have to be considered; whereas, if it is situated close to the generating apparatus, all of the above factors come into consideration, even on breakers having the same method of tripping, such as, for instance, "instantaneous trip." As stated above, an instantaneous direct-trip circuit breaker may work on the second cycle of a 25-cycle circuit when the current on short-circuit is practically at a maximum; whereas, an instantaneous relay-trip circuit breaker would not work earlier than in six cycles of 25-cycles. Considering this fact in connection with generators of widely different characteristics and in some cases having a very steeply decreasing short-circuit characteristic, the instantaneous relay trip circuit breaker would be compelled to break but a small portion of the current that a direct-trip circuit breaker would be forced to open in the same location.

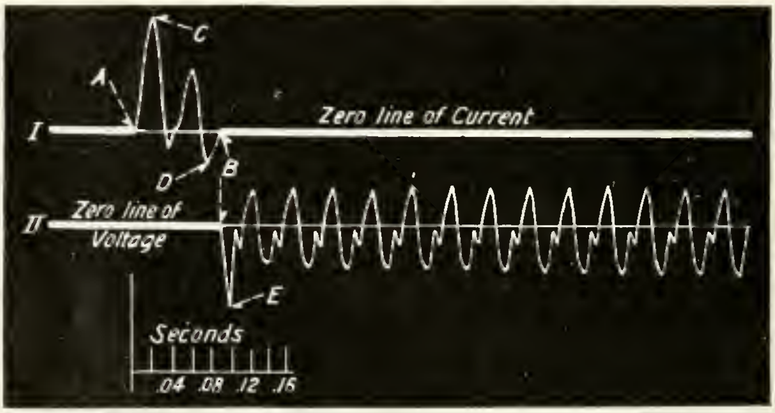

FIG. 2—DIRECT SHORT-CIRCUIT IN SAME LOCATION AS IN FIG. 1, THROUGH AN INSTANTANEOUS DIRECT-TRIP CIRCUIT BREAKER, WITH ALTERNATING-CURRENT TRIP MAGNET

It took slightly less than 2.5 cycles (about 0.09 seconds) for the circuit breaker to trip. A surge in voltage amounting to about twice normal value is shown at *E*, although the generator was not isolated, which might be sufficient to cause damage to weakly insulated apparatus.

In view of all the above facts, the following assumptions have ordinarily been made by circuit-breaker manufacturers in order to apply the ultimate kilovolt-ampere breaking capacity rating on the above basis to operating conditions. These assumptions are more or less arbitrary, and the actual characteristics or conditions should be known in order to modify the assumptions so as to secure a correct application of a given circuit breaker to given conditions.

It is assumed:—

1—That the generators have an inherent reactance of approximately eight percent, or, in other words, give a maximum current on the first wave of short circuit of 12.5 times the mean full-load current; and also that the sustained short-circuit current has a maximum value of three times the mean full-load current.

2—That the current at the time the circuit is opened is approximately 50 percent of that occurring on the initial wave; or in other words, 6.25 times the mean full-load current.

3—That the circuit breakers are very close to the generators or other source of power, so that the circuit reactance from the generators through the circuit breakers to the point of short circuit is practically negligible.

4—That the operation of the circuit breakers is normal for the particular type, and that the method of tripping is that known as "instantaneous," under which conditions the mechanism should be expected to operate in 0.1 to 0.2 seconds.

5—That the normal operating voltage which the circuit breakers are called upon to open is that on which their rating is based.

6—Where a circuit breaker is used at a lower voltage than the maximum for which it is designed, it is assumed that a one percent increase in kilovolt-ampere rupturing capacity is permissible for every one percent decrease in operating voltage.

The basis of this last arbitrary rule is partly the fact that the guarantee for double voltage would be zero kilovolt-amperes, and at normal voltage, 100 percent of the rating. A straight line drawn through these two points and carried through to zero voltage would give the increase above mentioned. Repeated tests have demonstrated that this arbitrary rule is conservative and field data of circuit-breaker operation form a further demonstration. Any standard circuit breaker will rupture a reasonable percentage of its rating at double voltage and it is also a fact that its circuit breaking ability would be almost infinite at a voltage slightly greater than zero. In view of this, it will be noted that the increase in rating would be a ratio greater than the first power.

The guarantees as to circuit-breaker operation ordinarily given by manufacturers are all based on some such assumptions as those stated above, and the nature of these assumptions must be known in order to correctly apply the circuit breakers. Since the manufacturer cannot know ordinarily the characteristics of the individual machines on whose circuits the circuit breaker is required to operate, it is evident that some such assumptions must be made in order to form a basis for a rating with respect to the kilovolt-ampere breaking capacity. As an evidence of the extreme variations in generator short-circuit characteristics, the curves shown in Fig. 3 have been plotted from oscillograms taken during a direct short circuit on several types of generators. The rating characteristics of the generators tested are presented in Table I, and the oscillograms from which the data was prepared are given in Figs. 4 to 11, inclusive. In order to obtain a ready basis of comparison, the currents in Fig. 3 have been plotted in terms of normal-load current. While certain general conclusions may be drawn from the type of generator, such, for instance, as that the high-speed turbo-generator of lower frequency will ordinarily have a higher short-circuit current than the low-speed engine or water-wheel type of generator, or a generator of higher frequency, the curves show some quite radical exceptions to any general rules, and in making a circuit-breaker application it is necessary to know the short-circuit characteristics of the particu-

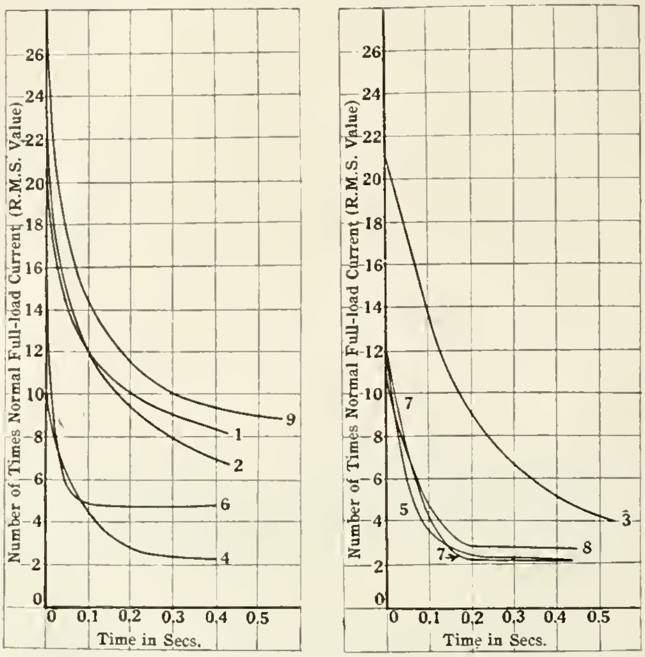

FIG. 3—SHORT-CIRCUIT CHARACTERISTICS OF ALTERNATING-CURRENT GENERATORS LISTED IN TABLE I

TABLE I—SHORT-CIRCUIT DATA ON ALTERNATING-CURRENT GENERATORS.

No.	K.V.A.	Volts.	Amperes.	Cycles.	R.P.M.	Type.
1	520	1 000	300	25	1 500	Turbo
2	1 250	2 400	300	60	3 600	Turbo
3	6 588	6 600	576	25	375	W. W.
4	7 500	12 000	360	25	300	W. W.
5	10 000	2 300	2 500	60	1 800	Turbo
6	12 000	11 000	630	25	116	W. W.
7	17 500	6 600	1 500	50	375	W. W.
8	17 500	6 600	1 500	50	375	W. W.
9	19 000	8 000	1 370	62.5	1 875	Turbo

lar machines under consideration. These may ordinarily be secured on application to the manufacturers of the machines, in case facilities are not available for testing at the installation.

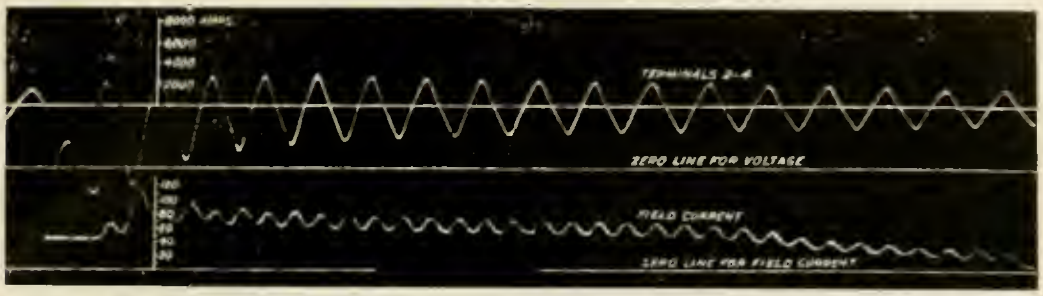

FIG. 4—SHORT-CIRCUIT ON ONE PHASE OF GENERATOR NO. 1, TABLE 1

In generators of very low inherent reactance the rate of decrease of current is usually more rapid than with those of high inherent reactance and at the time the circuit breaker opens, the kilo-

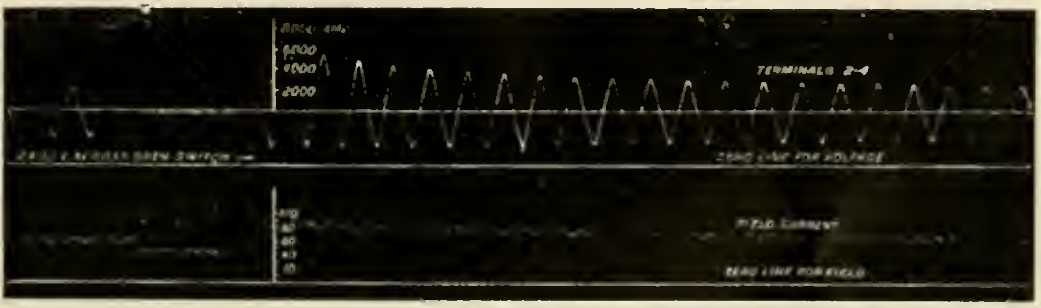

FIG. 5—SHORT-CIRCUIT ON ONE PHASE OF GENERATOR NO. 2, TABLE 1

volt-amperes may be one-fourth or less of the initial maximum rather than one-half, as assumed above. If the plant capacity is large and the inherent reactance is very low, it is sometimes desira-

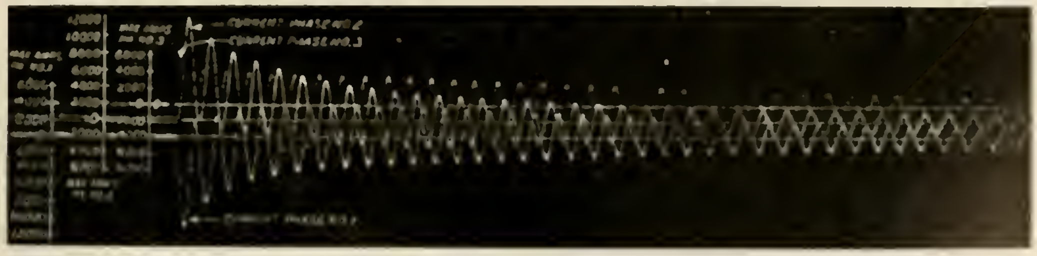

FIG. 6—SHORT-CIRCUIT ON ALL PHASES OF GENERATOR NO. 3, TABLE 1

ble to insert sufficient reactance in a circuit to limit the maximum short-circuit output from the machines. If there is sufficient reactance to definitely limit the output to suit a given circuit breaker, the addition of time-limit relays or non-automatic operation will not permit of this reactance value being reduced; that is, the rating of the circuit breaker cannot be increased by non-automatic operation or the use of time-limit relays, as would be the case if the inherent reactance of the generator were the only limiting feature.

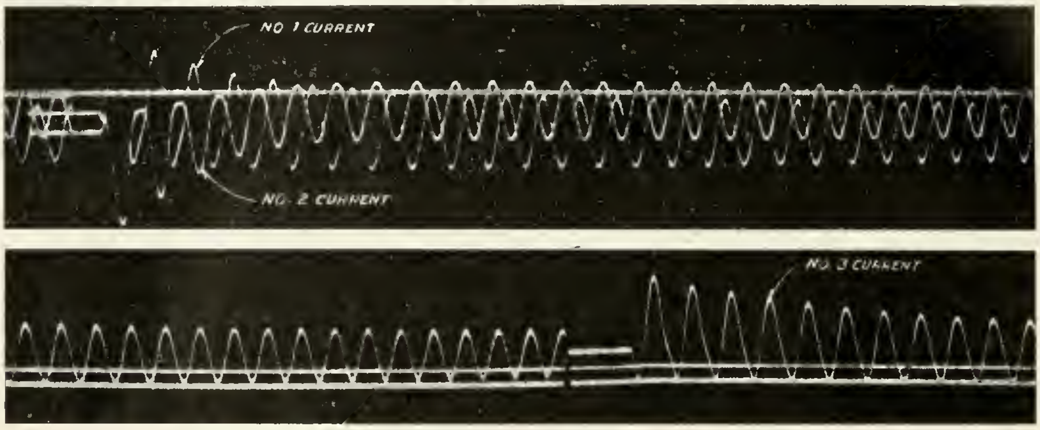

FIG. 7—SHORT-CIRCUIT ON ALL PHASES OF GENERATOR NO. 4, TABLE I

In view of the ambiguity of the present methods of rating oil circuit breakers and the consequent difficulty on the part of operators of understanding the relations between the capacity of the generators and that of the circuit breakers, an alternative proposition is to make the basis of rating, the actual maximum alternating current and alternating voltage that occurs at the time of rupture, and immediately thereafter, respectively, that the circuit breaker is capable of successfully controlling. By "successfully controlling" is meant that the breaker will rupture this rated current and voltage, and be in such operative condition that it can be immediately placed in service again. It is assumed that a systematic inspection will take care of depreciation in contacts and oil.

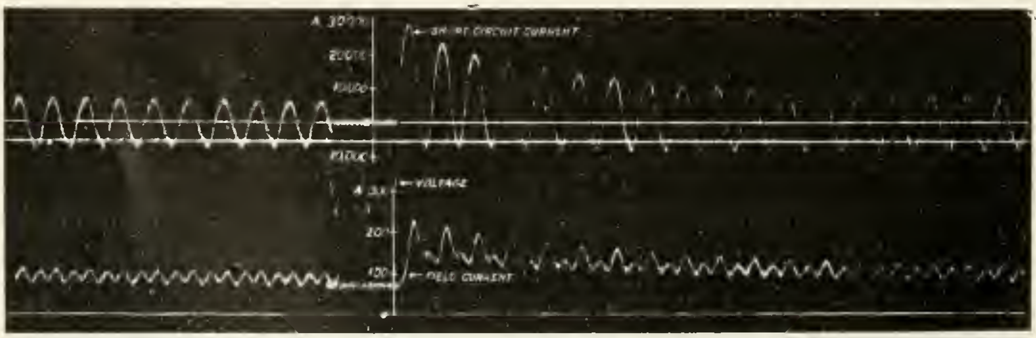

FIG. 8—SHORT-CIRCUIT ON ONE PHASE OF GENERATOR NO. 5, TABLE I

This basis of rating forms a statement of what the circuit breaker is actually capable of doing, and does not bear any relation to the size of the plant on which it may be used, without a further knowledge of the short-circuit characteristics of the generators or other synchronous apparatus, the inherent reactance of the apparatus and circuits up to and beyond the circuit breaker to the point where the overload occurs, the method of tripping the circuit breaker and the operating characteristics of the circuit breaker itself. Since all these things must be considered under any system of rating, it is believed that the selection of a suitable circuit breaker will be easier if the rating is in terms of only maximum volts and amperes, than under the present system of rating.

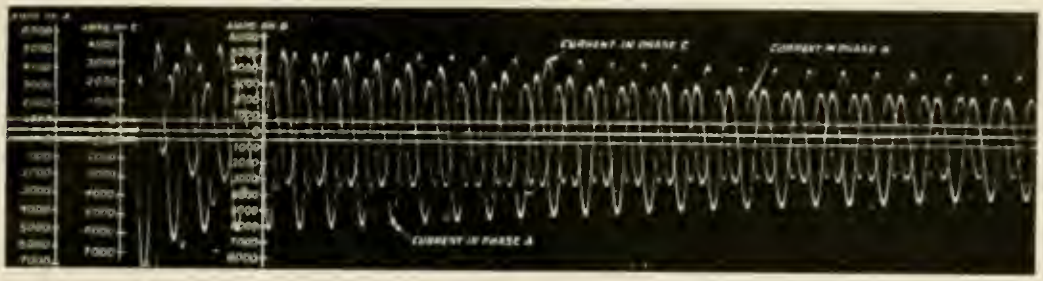

FIG. 9—SHORT-CIRCUIT ON ALL PHASES OF GENERATOR NO. 6, TABLE I

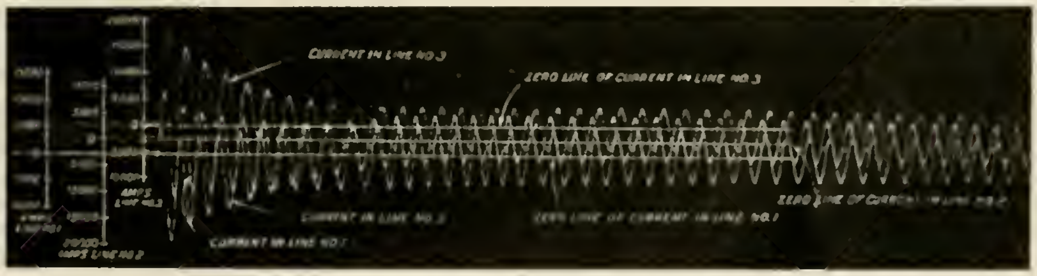

FIG. 10—SHORT-CIRCUIT ON GENERATOR NO. 7, TABLE I; TEST NO. 7, FIG. 3

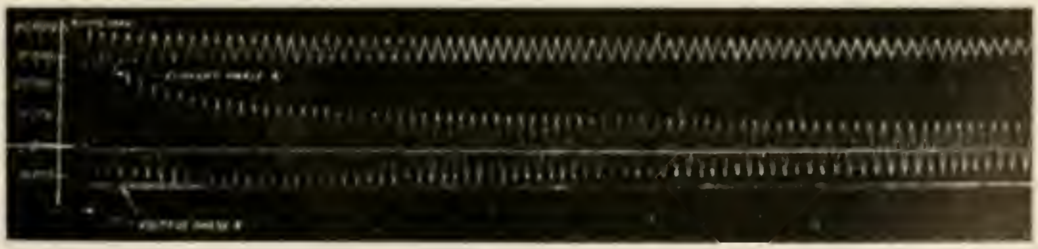

FIG. 11—SHORT-CIRCUIT ON ONE PHASE OF GENERATOR NO. 9, TABLE I

As at present rated, a circuit breaker is ordinarily guaranteed by the manufacturers to be able to successfully control a certain kilovolt-ampere capacity in synchronous apparatus connected to a circuit. As stated above, this is made on the assumption that the circuit is opened at approximately 50 percent of the maximum current rush, and that the inherent reactance of the generators is approximately eight percent. Then a circuit breaker which would be rated at 22 400 k.v.a. ultimate breaking capacity would be capable of instantly opening a circuit in which 140 000 k.v.a. is obtained under short-circuit conditions, on a three-phase basis. As the assumption is made that the circuit is not opened on the initial wave of short circuit, but at a value of approximately 50 percent of the maximum current rush, the guarantee indicates that the circuit breaker will successfully clear a short circuit on a generator capacity which will give 280 000 k.v.a. instantaneous maximum, three-phase, under short-circuit conditions. This maximum capacity can be translated into any other generator capacity by a knowledge of the generator inherent reactance plus external reactance, if any. For instance, assuming the inherent reactance of the generator and circuit up to the circuit breaker to total ten percent, the generator capacity on the above basis would then be 28 000 k.v.a.; whereas, with an inherent reactance of but five percent the generator capacity would be but one-half of that, or 14 000 k.v.a., and proportionately with any other reactance. The generator inherent reactance may vary from two to twenty percent, and as the external reactance may be of almost any value, and as the rate of diminution of short-circuit current in generators varies greatly, it can readily be seen that the characteristics of the generator and circuits must be determined before a correct circuit-breaker application can be made.

Where a group of circuit breakers having a definite time-limit trip are to be used on feeders, and a main circuit breaker having instantaneous trip is to be used between them and the main bus-bars, the feeder circuit breakers can be of comparatively low breaking capacity, the main high-capacity circuit breaker acting as a safeguard for all.

The location of the circuit breaker electrically in the system affects the work that may come upon it in still another manner. As an example assume two circuit breakers located at the ends of a high-voltage transmission line, and a short circuit produced just beyond the circuit breaker at the receiving end. If this circuit breaker cleared the short circuit it would be compelled to interrupt a current flow which would be limited by the reactance of the generators and lines between the generators and the points of short circuit. If the circuit breaker at the station end cleared this same short circuit, it would be compelled to perform the same work as the circuit breaker at the receiving end, and in addition would have to take care of the stored energy in the transmission line, which tends to re-establish or maintain a potential difference for a period immediately subsequent to the interrupting of the dynamic flow of current. This action would be rendered still more severe by the fact that the insulating value of the oil may be somewhat impaired by the arc of the dynamic current immediately preceding, before the circuit breaker has completed its cycle of operation. In addition to this added work imposed on the circuit breaker at the generating end, if it is located and operated in such a manner that the entire output of a relatively large plant passes through it and it is caused to open under short-circuit conditions, the stored energy in the generating equipment, transformers, etc., is dissipated therein, in addition to the work of circuit breaking; whereas, when a number of lines and circuits including other apparatus are operated in parallel with the one that may be in trouble, this energy is dissipated in the system.

It will be noted from the several foregoing factors which affect the application of oil circuit breakers, that the present basis of rating covers only a given case; hence, to make the best possible application, the ratings so given should be exceeded in some cases and reduced in others, and the more data there is available, the more accurately can a suitable circuit breaker be selected.

THE POWER PROBLEM IN BITUMINOUS COAL MINING

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IN the year 1920 some 835 000 000 tons of bituminous coal will be mined in the United States. This amount is over twice the quantity produced in 1909. With this great increase in the demand for bituminous coal one would, at first glance, consider coal mining a very profitable business. However, to earn a reasonable profit becomes a more difficult problem each year. These statements are borne out by the United States Census Reports and the Geological Survey on the bituminous coal industry, from which the data given in this paper is compiled. From Table I it may be seen that this country is changing very rapidly from an agricultural to a manufacturing one, as indicated by the remarkable *increase in the demand for coal per capita.* For the past fifty years the population has increased at an average of 23.5 percent per decade. The demand for coal per capita has increased from 0.26 tons in 1860 to 4.54 tons in 1910. During the past two decades, the quantity of coal mined has increased at an average rate of 62 percent per capita per decade.

TABLE I—COMPARATIVE ANALYSIS OF BITUMINOUS COAL MINED IN PROPORTION TO THE POPULATION

Year	Population		Quantity of Coal Mined			
					Per Capita	
	In Numbers	Percent Increase in 10 years	Tons per year	Percent Increase in 10 years	Tons	Percent Increase in 10 years
1860	31 443 000	..	6 494 000	...	0.262	...
1870	38 558 000	22	17 371 000	167	0.45	73
1880	50 155 000	29	42 831 000	147	0.855	89
1890	62 947 000	25	111 302 000	159	1.77	108
1900	75 994 000	20	212 316 000	91	2.8	64
1910	91 972 000	21	417 111 000	96	4.54	60

If these averages hold true until 1920 the coal mined per capita will be 7.36 tons. If the population increases at the same rate as during the past 50 years, there will be 113 475 000 inhabitants in the United States in the year 1920, and on this basis the coal mined in 1920 will amount to 835 176 000 tons. This is an increase of 100 percent over that mined in 1910. By comparing this increase with similar figures for coal production during the past fifty years, the amount predicted for 1920 seems entirely possible.

In 1890 this country ranked second among the coal producing countries of the world. At that time Great Britain's production exceeded ours by about 30 percent. However, by 1900, the United States had overtaken Great Britain and has since maintained the advantage with an increasing lead each year. In 1911 the coal production of this country exceeded that of Great Britain by 60 percent. The quantity of bituminous coal mined in the United States each year from 1890 to 1912 is shown graphically in Fig. 4.

In almost any other industry, such an increase in the demand for its product would have caused a considerable increase in the price of its commodity. However, this did not take place in the coal industry. In fact, at times the selling price was so low that it was a difficult task for the operators to earn a legitimate profit. This condition of affairs is caused by the constant increase in competition. As the demand increases, new workings are continually opening up, thus making an output in excess of the demand—a condition which has existed for the past 25 years. The owners of coal lands are always looking for an opportunity to open them up. The railroads also encourage competition by continually extending their lines into new fields, thereby securing additional tonnage and at the same time, low priced fuel for their own consumption. The effect of keen competition upon the selling price of coal is shown in Fig. 4, in which is indicated the average selling price per ton per year at the mine for a period of 30 years.

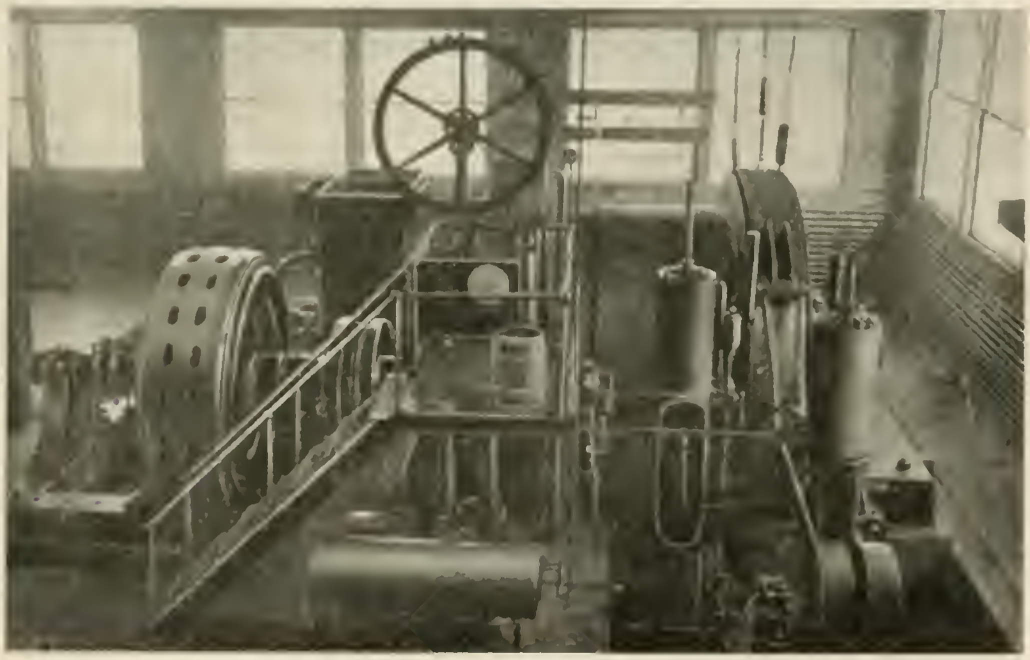

FIG. 1—A 750 HORSE-POWER ALTERNATING-CURRENT MOTOR DRIVING A MINE HOIST

To make a profit with the low selling price and the continual increase in the cost to produce coal, is indeed a problem. One solution is to increase the output. Mr. Edward W. Parker states "that the present bituminous mines in the United States are capable of producing 600 000 000 to 700 000 000 tons per year." He claims that this is possible without opening up another new working. To do this, of course, requires ample transportation facilities and plentiful labor supply.

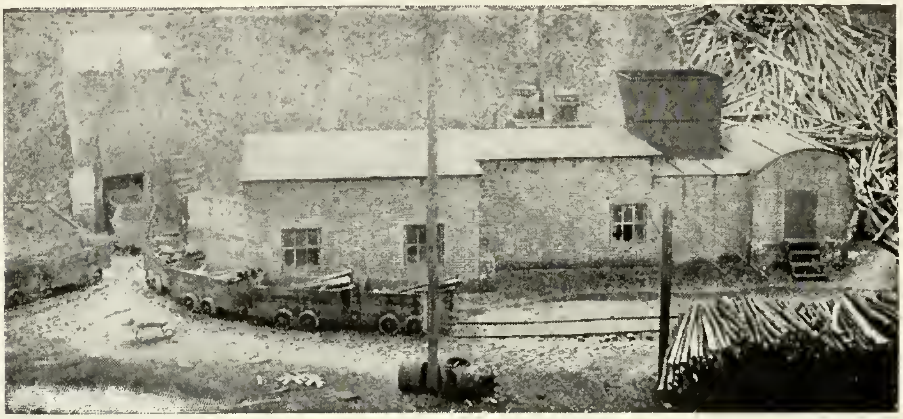

FIG. 2—FAN HOUSE FOR AN ELECTRICALLY-DRIVEN FAN

TABLE II—CENSUS ANALYSIS OF THE BITUMINOUS COAL INDUSTRY—ALL COAL COMPANIES

No.	Items	1902	1909	Percent Increase in 7 Years.
1	Number of companies........	4 409	3 503	—20.3
2	Number of mines............	5 652	6 013	6.4
3	Total capital................	$440 800 000	$1 062 197 083	141
4	Primary horse-power.........	521 165	1 227 401	135
5	No. wage earners............	280 638	569 789	103
6	Wages......................	$181 482 288	$ 294 196 488	62
7	No. salaried employees........	19 871	22 800	14.7
8	Salaries.....................	$14 511 924	$21 800 895	50
9	Misc. expenses*..............	$16 774 459	$29 691 324	77
10	Cost of supplies..............	$24 798 922	$48 000 000	94
11	Contract work................	$ 1 244 114	$ 2,207 672	77
12	Quantity coal mined (tons)...	260 216 844	379 744 257	45
13	Value of product............	$290 858 483	$405 486 777	39

*Includes royalties, rent of mines, taxes, office rent and sundry expenses.

THE PRESENT STATUS OF THE INDUSTRY

The condition of the bituminous industry in 1909, is shown in Table II, the figures giving the increase in seven years dating from 1902 to 1909. The percents shown in the last column would apply to the conditions of today.

Table II shows that the number of companies decreased 20.3 percent. This does not mean that competition decreased. The number of mines increased 6.4 percent. These figures indicate that the companies became larger and stronger. This is borne out by the next item, which shows that the total capital increased 141 percent. Some may consider that a large portion of the increased capitalization was water. However, the next item shows that this is not the case. On the contrary, the primary horse-power increased 135 percent. This means that the capacity of the power plants had to be increased this amount, which was caused by the installation of new and heavier equipment in and around the mine. The new machinery must have required the expenditure of a considerable portion of the new capital. All the remaining items in this table show a material increase.

TABLE III—CENSUS ANALYSIS SHOWING AVERAGES UPON PER TON BASIS

No.	Item	1902	1909	Percent Increase in 7 years
1	Number of tons coal mined....	260 216 844	370 744 257	45
2	Capital........................	$1.695	$2.80	65.3
3	Contract work..................	$0.00478	$0.00583	21.9
4	Number of wage earners......	0.00107	0.0015	40.3
5	Number of salaried employees.	0.0000764	0.0000602	−21.2 Dec.
6	Primary horse-power..........	0.002	0.00324	62
7	Wages..........................	$0.697	$ .775	11.2
8	Salaries.......................	$0.0558	$0.0575	3.4
9	Cost of supplies...............	$0.095	$0.126	32.6
10	Misc. expenses*................	$0.0643	$0.0785	22
11	Value of product..............	$1.115	$1.07	— 3.9 Dec.

*Includes royalties, rent of mines, taxes, office rent and sundry expenses.

Table III is an analysis of the preceding one and shows the same items worked out upon a tonnage basis. It shows most conclusively that the cost per ton of coal mined has increased and that the profits have decreased. For instance, in 1902 the average selling price per ton was $1.115 and the average operating cost to mine coal was $0.912, leaving a profit of 20.3 cents. In 1909 the average selling price was $1.07 and the average cost $1.037, leaving a profit of only 3.3 cents per ton.

These operating costs do not include all the fixed charges. They include only the cost of wages, salaries, cost of supplies and miscellaneous expenses. Contract work (Item 3) is given to show the amount of new development work.

The increase in capital per ton of coal mined, of 65.3 percent in seven years is interesting. It shows that the mine operators are continually spending money for equipment and improvements which they anticipate will reduce the cost of mining. In 1902 there was $1.695 invested for every ton of coal mined per year. In 1909 the capital had increased to $2.80 for every ton of coal mined per year. If the economies anticipated by the operators had worked out, the other item of expense in the column under 1909, would have been reduced; instead, each item of expense shows an increase.

From the foregoing it is seen that the capital account has reached such proportions that the future profits must be obtained through greater output and greater economies in the operation of the workings, and the investment must be kept down to a minimum.

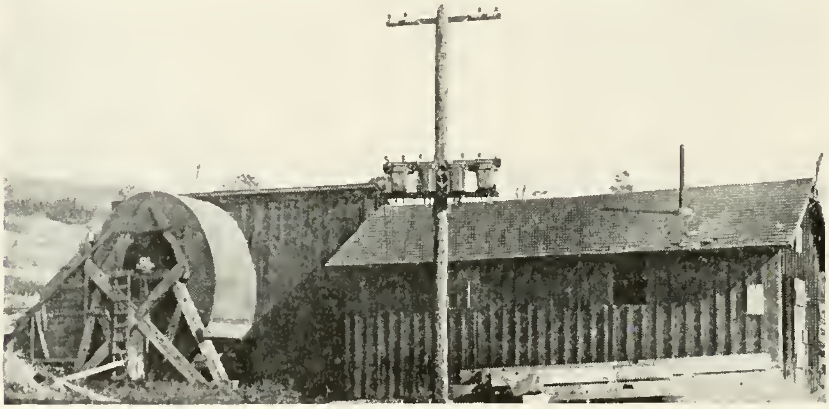

FIG. 3—SUBSTITUTING ELECTRICITY FOR STEAM
Note idle exhaust pipe.

COAL MINING IS A POWER PROPOSITION

The coal mining industry is undergoing a very rapid evolution. Only a few years ago it was strictly a mining proposition; coal was mined entirely by manual labor and hauled by mules. Today almost 50 percent of the entire production is mined by machinery and hauled by locomotives. The industry is now becoming a combination of both a mining and a power proposition.

After the mine operators had gone to the expense for mining machinery, etc., the cost to produce coal should have been reduced. However, the new order of things brought about conditions of their own, which, in most cases, increased the cost of mining. The profits in the future depend in a great measure upon the solution of these new problems. They offer the greatest of opportunities to effect economies in almost every working. This does not indicate that the man in charge is negligent. A mine superintendent is essentially a miner. He has been selected by the management because of his practical knowledge on the subject of mining coal. Power is entirely out of his line. The production of power, its proper distribution, and its use in a mine, requires the work of those who have made the subject a special study, in other words, specialists.

In the past the operators have made it a general practice to install isolated power plants and generate their own power. However, a large number of these plants have since been abandoned and the operators are now buying electricity from the nearest power company. Many of the new workings opened up during the past few years are operating entirely from purchased power. It seems somewhat inconsistent to think that a central station can afford to buy coal, pay freight and then sell the power back to the coal mine. Nevertheless this is the case; furthermore, the operators are finding it cheaper than producing their own power.

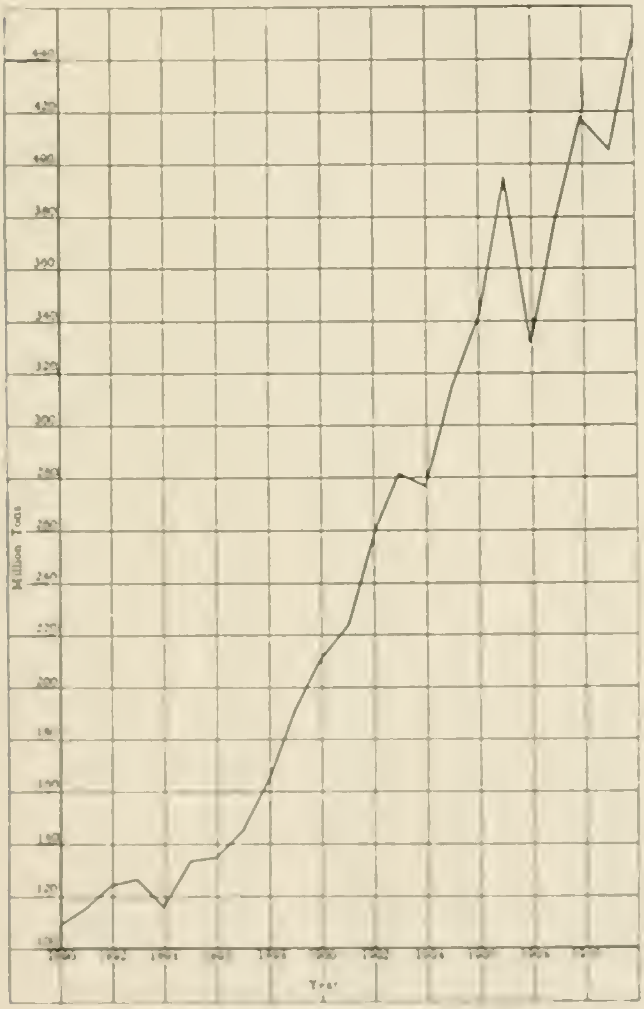

FIG. 4—AMOUNT OF COAL MINED YEARLY

One of the principal advantages of central station service is that it allows extensions to be made and more mining machinery to be added without making expensive additions to a power plant. This can best be explained by citing the experience of one coal company, which will undoubtedly be similar to that gone through by many others. This company opened up their workings eight years ago and invested $18,000 in a power plant. They anticipated that this plant would meet their requirements for years to come. They increased their tonnage to such an amount that three years ago they found it necessary to increase the capacity of the power house. This required an additional investment of $14 000, or a total of $32 000. Later, they extended their workings to such distances that it became a problem to deliver electricity at proper voltages. At times the quantity of coal mined was considerably less than it should have been, due to this one difficulty. Early this spring they decided to make further additions to the power plant to take care of the new conditions before them. The changes contemplated would cost $18 000, and would make a total of $50 000 invested in a power plant.

After studying the matter thoroughly this company decided to purchase their power from the local central station. The investment required would be very much less than that required for power plant extensions; also since making the change they find it considerably cheaper than their former power costs.

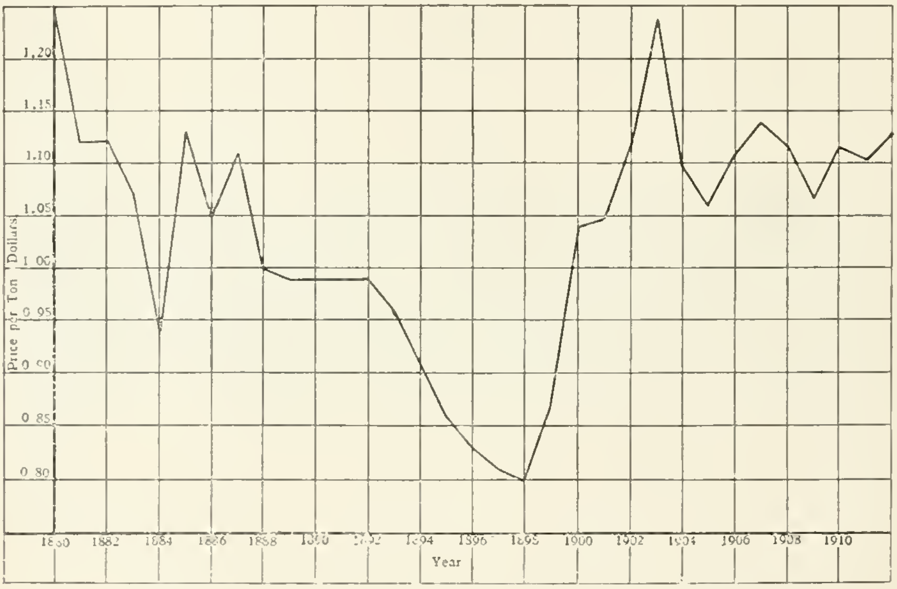

FIG. 5—SELLING PRICE OF COAL PER TON AT THE MINES

POWER REQUIREMENTS

To meet the conditions arising due to an increase in the power requirements, is oftimes a most perplexing problem. The solution may lie in any one of the following three plans.

1—By increasing the capacity of the present plant.

2—By building an entirely new modern power plant.

3—By purchasing central station power.

To decide on which plan, requires considerable study. The operator should first determine from the present plant, details as

TABLE IV—COMPARATIVE COST OF POWER ISOLATED PLANT vs. PURCHASED POWER IN BITUMINOUS COAL MINES

Isolated Plant Power							Purchased Power		
1	2	3	4	5	6	7	8	9	10
							Rate $11.20 per Hp + 0.746c. per Hp-hr.		
								Saving per Hp-hr.	
No. of Mine	Price of Fuel	Hp of Engine	Max. Demand	Per cent Load Factor	Hp-hr. Consumed per Year	Cost per Hp-hr., Cents	Cost per Hp-hr., Cents	Cents	Per Cent
Group A—Steam Engines to 50 Hp									
1	$0.75-c	50	60	22	96 500	2.7	1.41	1.29	47.8
Group B—Steam Engines from 51 to 100 Hp									
2	$0.75-c	75	70	25.7	160 000	2.6	1.20	1.40	53.8
Group C—Steam Engines from 101 to 200 Hp									
3	0.75-c	180	200	50	79 000	1.40	1.02	0.38	27.1
4	0.75-c	180	160	19	300 000	2.40	1.34	1.06	44.2
5	0.75-c	200	285	24	421 000	2.20	1.50	0.70	31.4
	Average Cost					2.00	1.28	0.72	36
Group D—Gas Engines from 101 to 200 Hp									
6	$0.01-g	130	150	20	228 000	2.50	1.48	1.02	40.7
7	0.01-g	130	150	22	251 000	2.40	1.41	0.99	41.2
8	0.04-g	150	90	22	289 000	2.00	1.09	0.91	45.5
	Average cost....................................					2.30	1.32	0.98	42.6
Group E—Steam Engines from 201 to 500 Hp									
9	$0.75-c	225	300	30	593 000	1.50	1.31	0.19	12.6
10	0.75-c	250	175	15	328 000	2.00	1.34	0.66	33.0
11	0.75-c	260	280	19	434 000	3.00	1.47	1.53	51.0
12	0.75-c	300	150	17	445 000	2.30	1.12	1.18	51.3
13	0.75-c	300	320	31	815 000	1.90	1.18	0.72	37.9
14	0.75-c	300	300	50	1 312 000	1.40	1.00	0.40	28.6
15	0.75-c	300	375	50	1 318 000	1.30	1.06	0.24	18.4
16	0.70-c	300	300	39	1 024 000	1.30	1.07	0.23	17.7
17	0.75-c	300	160	13	342 000	2.00	1.26	0.74	37.0
18	0.75 c	300	325	24	632 000	1.90	1.32	0.58	30.5
19	0.75-c	325	300	45	1 283 000	1.40	1.01	0.39	27.8
20	0.75-c	340	375	41	1 224 000	1.20	1.09	0.11	9.1
21	0.75-c	350	400	31	950 000	1.50	1.21	0.29	19.3
22	0.75-c	350	400	31	951 000	1.40	1.21	0.19	13.5
23	1.50-c	350	350	17	522 000	2.90	1.49	1.41	48.7
24	0.75-c	400	450	18	632 000	1.00	1.54	*0.54	*54.0
25	0.75-c	400	180	16	562 000	2.20	1.10	1.10	50.0
26	0.75-c	400	425	12	422 000	2.80	1.86	0.94	33.5
27	0.75-c	450	400	21	830 000	1.90	1.28	0.62	32.6
28	0.75-c	480	375	19	800 000	1.30	1.27	0.03	2.3
29	0.75-c	500	350	16	700 000	1.60	1.30	0.30	18.7
30	0.75 c	500	450	39	1 710 000	1.30	1.04	0.26	20.0
31	0.75-c	500	500	18	790 000	1.60	1.45	0.15	9.3
	Average cost					1.77	1.26	0.50	28.8
Group F—Gas Engines from 201 to 500 Hp									
32	$0.04-g	300	250	17	447 000	2.00	1.37	0.63	31.5
Group G—Steam Engines from 501 to 1000 Hp									
33	$0.75-c	575	650	31	1 562 000	1.50	1.20	0.30	20
34	0.55-c	600	625	12	651 000	2.50	1.86	0.64	25
35	0.75-c	700	700	26	1 595 000	1.30	1.24	0.06	4.6
36	0.75-c	950	900	65	5 420 000	0.90	0.932	*0.032	*3.5
	Average cost					1.55	1.30	0.25	16
Group H—Gas Engines over 1000 Hp									
37	$0.05-g	1500	1500	24	3 160 000	1.10	1.27	*0.17	*15
38	0.05-g	1500	1500	24	3 160 000	1.40	1.27	0.13	9.2
39	0.05-g	1700	1500	24	3 680 000	1.40	1.24	0.16	11.4
	Average cost					1.30	1.24	0.06	4.6
Group I—Steam Engines over 1000 Hp									
40	$0.75-c	1800	2000	18	2 840 000	1.20	1.53	*0.33	*27.5
	Average for all mines					2.13	1.32	0.81	38

*Note—These quantities are negative and show an increase of cost by the purchase of power to the maximum demand for power per ton of coal mined, the quantity of power required per ton of coal mined, and the cost for power per ton of coal. There are always certain parts of the load that remain fairly constant irrespective of the quantity of coal mined, such as that required for the fans, pumping, lighting, etc.. The information as to the demand and the quantity of power required by this part of the load should be obtained separately from that required for mining, haulage, etc. With this information as a working basis, the plan to adopt can be decided upon by determining which plan offers the most economical operation with a minimum investment and at the same time allows for future growth.

An analysis such as outlined will, in almost every instance, result in favor of purchased power. This, of course, is assuming that the rates are such as usually quoted by power companies. The information in Table IV, given in support of this statement, was obtained from actual tests in mines located in Pennsylvania, West Virginia and Ohio. In each case, excepting mines *24, 36, 37* and *40,* the data shows that purchased power was cheaper. This table is divided into groups according to the size of engines and contains data on both steam and gas engines. The groups are arranged as follows:—

Group *A*—Steam Engines—50 hp and under.
“ *B*— “ “ from 51 to 200 hp.
“ *C*— “ “ “ 101 to 200 hp.
“ *D*—Gas “ “ 101 to 200 hp.
“ *E*—Steam “ “ 201 to 500 hp.
“ *F*—Gas “ “ 201 to 500 hp.
“ *G*—Steam “ “ 501 to 1 000 hp.
“ *H*—Gas “ “ 1 001 hp and over.
“ *I*—Steam “ “ 1 001 hp and over.

Columns *8, 9* and *10* show the cost per horse-power-hour and the savings effected with power purchased at a given rate, the savings being shown in cents and also upon a percentage basis. The rate used for central station power is figured at $15.00 per kilowatt per year for the maximum demand and one cent per kilowatt-hour for the current consumed. On a horse-power basis this rate would be $11.20 per horse-power maximum demand plus 0.746 cents per horse-power-hour. All the details in the table are worked out upon a horse-power-hour basis. Column *2* shows the price the operators charged themselves for fuel; *75-c* indicates the price charged for coal was 75 cents per ton; *4-g* indicates that the company used natural gas at four cents per thousand cu. feet.

It seems to be common practice among many operators to charge themselves at the rate of 75 cents per ton for the coal used for power purposes. As a matter of fact it costs them whatever price it would bring in the market. Again, many operators insist that they use slack and offal from the mine, coal that, for a greater part, is unsalable. A visit to the boiler rooms will show that by far the greater number of them are using run of mine.

It will be but a matter of a few years when the majority of coal mines will be operated from central stations. To illustrate the trend of the times, the Virginia Power Company, a $10 000 000 company in the New River district, was developed because of the opportunities existing there in the coal field. The West Penn Electric Company connected the first coal mine on their lines in 1896, a load of 120 horse-power. Today they have contracts with mine operators aggregating over 20 000 horse-power. They anticipate that this will exceed over 30 000 horse-power before the closing of the year.

Another point worth mentioning is that the total capital of all the power companies exceeds $2 500 000 000. This amount is 2.35 times greater than the total capital of all coal companies. Again, the income of central station companies from the sale of electricity for power purposes has increased 746 percent during the last ten years. This indicates that power users in all lines of industry are gradually adopting purchased power.

SIXTY CYCLE ROTARY CONVERTERS*

B. G. LAMME

ONE of the most significant developments in the past year has been the greatly increased purchase of large 60 cycle rotary converter by central station plants. Here is an example of a type of machine which has been more or less discredited in the past, but which, all at once, is coming prominently to the fore. The present machine itself is not radically different from its older forms, but it contains many minor improvements which, individually, do not stand out prominently, yet collectively, have served to overcome those little difficulties which formerly were just sufficient to put the machine in the questionable class. However, a number of general conditions were also involved in this improvement. It is the purpose of this paper to show wherein the new machine is superior to the older type, and also to indicate wherein a number of modifications, each in themselves of a small amount, have combined to form a relatively large improvement.

Shortly after the 25 cycle rotary converter began to be prominent in electrical work, that is, about 15 to 18 years ago, the problem of 60 cycle converters was also presented, as the relatively numerous 60 cycle plants also had need of economical means for transforming to direct current. In consequence, there being a field for 60 cycle converters, such machines were built and installed in a number of places. These early machines were in some cases fairly successful, while in others, they were failures. Apparently, in some of these cases of failure, the converter itself was not entirely to blame, as it was operated under conditions which would now be considered impracticable, with our present knowledge and experience.

These early 60 cycle converters were very greatly handicapped in design by the limitations of commercial and manufacturing practice of those days. Relatively low speeds were considered necessary from the commercial standpoint, and with 60 cycles, this meant a large number of poles, even for relatively small outputs. Also, manufacturing limitations called for relatively low peripheral speed of the commutators. In those days, commutator speeds of much in excess of 4 000 feet per minute were considered excessive and unduly dangerous, both from the manufacturing and operating standpoints. Herein was a handicap of the worst sort upon the design. The peripheral speed of the commutator is equal to the distance between adjacent neutral points multiplied by the number of alternations per minute (revolutions per minute × no. of poles). On this basis, 3 600 feet per minute peripheral speed with 60 cycles per second (7 200 alternations per minute), gave one-half foot, or six inches, between adjacent neutral points. Even 4 200 feet peripheral speed gave only seven inches between neutral points. It is obvious therefore that, even with this higher peripheral speed of the commutator, there was undue crowding of the brushholders, which in itself was a bad feature. But the worst feature was in the fact that, with only seven inches between commutator neutral points, the maximum permissible number of commutator bars was unduly limited. Assuming, for example, a thickness of bar plus mica of 3/16 inch, which is very thin, the seven inches between neutral points would allow about 36 commutator bars between neutral points, or per pole. This number was ample for 250 to 300 volt machines, but for 600 volts, experience indicated that it was on the ragged edge, especially with the field flux distributions obtained with those early machines. In consequence, 60 cycle converters for 250 to 300 volts, rendered a better account of themselves than the 600 volt machines, and the latter were very much inclined to flash at times, due to the small number of commutator bars, and a high maximum voltage between bars.

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*A paper read at the annual convention of the Association of Edison Illuminating Companies, at Cooperstown, N. Y., September 9, 10 and 11, 1913. Reprinted by permission.

The field flux distribution had something to do with the questionable operating conditions. With these earlier machines, very high peripheral speeds of the armature core were considered objectionable, for several reasons. One was, that the constructions of that time did not allow very high peripheral speeds of the armature windings, and a second reason was that, with the relatively low speeds, and consequent large number of poles, the armature dimensions and cost would have ben excessive for a given output. In general, a 12 inch pole pitch was considered as large as desirable or practicable, which corresponds to 7200 feet per minute at 60 cycles per second.

With this small pole pitch, in order to obtain a sufficiently wide commutating zone between the poles, it was necessary to make the poles relatively narrow. The use of narrow poles led into one difficulty, as regards flashing, as will be explained later, while widening the pole and narrowing the interpolar space led into another difficulty of flashing which was equally serious. The situation can be illustrated by Figs. 1 and 2. In Fig. 1 the field flux distribution is indicated for an extreme case of a pole face as wide as eight inches and with only four inches interpolar space, the total pole pitch being 12 inches, and the poles without polar horns. The "field form," which indicates the flux distribution, in this case has a relatively wide top, and the proportions are such that the maximum e.m.f. between bars is about 40 percent greater than the average e.m.f. per bar. With 36 commutator bars, for instance, at 600 volts, the average volts per bar would be 16.7, and the maximum voltage per bar almost 24, which, in itself, may be a safe figure if never exceeded. However, the flux distribution in the interpolar space, as indicated by Fig. 1, is such that there is almost no width to the neutral or commutating zone, and therefore the brushes are short-circuiting the armature coils in an active field, even at no load, and, in some cases, this short-circuiting action may be so great that there are excessive local currents in the brushes. Furthermore, with the neutral point so narrow, a very slight forward shifting of the brushes, to take care of load conditions, would place the brush in such a strong field at no load, that there is danger of flashing when the load goes off, or changes suddenly. Therefore, with such proportions, the neutral point would be too narrow for reasonably safe operation. The remedy for this particular condition, with these former machines, was obviously in the use of wider interpole spaces, and consequently narrower poles, the pole pitch being limited to about 12 inches as previously stated.

In Fig. 2 is illustrated the conditions with the wider interpolar space, and narrower pole face, these being taken as 5.5 and 6.5 inches respectively, instead of four and eight inches. Obviously the flux conditions in the interpolar space are much better than in Fig. 1, and it should be possible to shift the brushes slightly for full-load conditions without excessively bad conditions as regards sparking and flashing at no load. But the same figure also shows that the field flux distribution as a whole is considerably narrower at the peak value than in Fig. 1, and therefore the ratio of the maximum value of the e.m.f. per commutator bar to the average e.m.f. is much greater. In this case, the maximum per bar is about 65 percent greater than the average, and, with 16.7 average per bar, the maximum becomes almost 28 volts, which is in the danger zone as regards arcing between bars, except in relatively small machines. Therefore, in overcoming the sparking and flashing difficulties incident to the narrow neutral zone of Fig. 1, an equivalent difficulty is encountered, due to the narrow field distribution, or field form. Plainly, in these older machines, which ever way we turned, we were in difficulty.

An obvious remedy for the above difficulties was in the use of wider pole pitches, which would allow both the commutating or neutral zone of Fig. 2, and the wider field form of Fig. 1. But increasing the pole pitch, with a given number of poles and given speed, means increasing the diameter of the armature, and even though the armature could thereby be narrowed, the cost of the machine of larger diameter would necessarily be somewhat increased. The remedy for this condition was a reduction in the number of poles as the pitch was increased, thus keeping down the size of the armature for a given output. But reduction in the number of poles necessarily means higher speeds, which were formerly considered commercially objectionable, as no one had yet been educated up to high speeds. Therefore, between commercial limitations, difficulties in design and manufacturing conditions, the 60 cycle converter was in a bad way. Mild attempts were made from time to time to increase the speed by decreasing the number of poles, but this could only be done commercially in relatively small steps. In such increases in speed, and decrease in the number of poles, other difficulties began to be encountered, such as somewhat poorer inherent commutating characteristics, due to the higher speed and greater current per brush

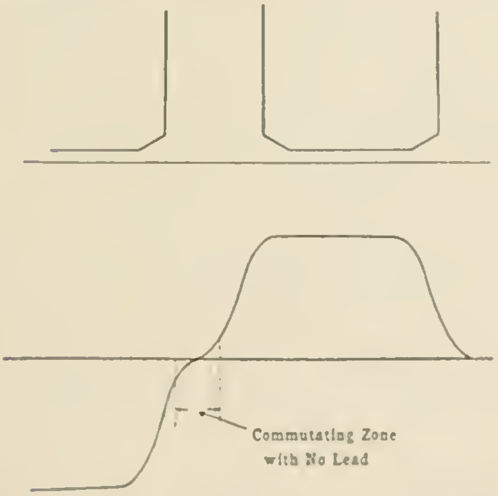

FIG. 1—FIELD FLUX DISTRIBUTION FOR AN EIGHT INCH POLE FACE AND FOUR INCH INTER-POLAR SPACE

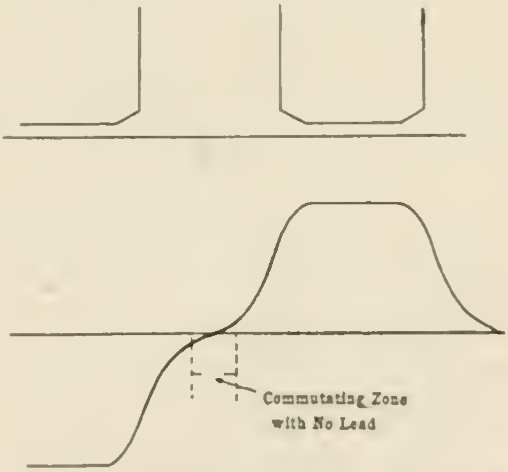

FIG. 2—FIELD FLUX DISTRIBUTION FOR A 6.5 INCH POLE FACE AND 5.5 INCH INTER-POLAR SPACE

arm to be commutated. The higher the speed was made, and therefore the more commercial the machine became as regards size and cost, the greater were the inherent difficulties in the design. However, with increased experience in commutator constructions, one great advance was made by increasing the commutator speeds of the 60 cycle converters. Instead of approximately seven inches between neutral points, the distance was increased to eight or nine inches for 600 volts, giving peripheral speeds of 5 100 to 5 400 feet per minute at the commutator face. This allowed as many as 45 to 48 commutator bars per pole, which is well within the range of good direct-current 600 volt practice. This increase in the number of bars reduced the average and the maximum volts per bar. In this manner, one of the principal weaknesses of the former designs was eliminated. Also, by improved mechanical design, which allowed higher peripheral speed of the armature windings, the pole pitch could be increased to about 16, instead of 12 inches, without an unduly large diameter of armature for a given output. This also allowed a much better field flux distribution, or field form, such as in Fig. 1, and the better interpolar space of Fig. 2. In consequence, the maximum voltage per bar on the 60 cycle converters has been brought down well within accepted practice for 600 volt work. For lower voltage work, these limitations have never been so prominent, but the same steps in the development have proven advantageous in lower voltage machines also.

With increased speed and decreased number of poles, the current per brush arm on the larger 60 cycle converters has gradually increased until it is practically double what it was on former machines of the same capacity. This higher current per arm, with the increased number of commutator bars per pole, and the higher speeds, all tend toward making the commutation problem more difficult. But at this stage in the development, the commutating pole began to loom up as a possibility in rotary converters, and this has furnished the latest important step in the improvement of these machines. By the addition of commutating poles, still higher speeds are permissible than formerly. While relatively high speed converters of large capacity can be made without commutating poles, yet the addition of such poles has rendered the design less difficult and has allowed still further increases in speed, which are very welcome in the way of improving the standing of the 60 cycle converter. With these higher speeds and greater outputs, with a given diameter of machine, the losses have not increased anything like in proportion, so that the efficiencies of the 60 cycle converters have gradually been increasing until now they are treading on the heels of the 25 cycle machine. In fact, when the greater efficiency of the 60 cycle step-down transformers is taken into account, the difference between the efficiencies of 60 cycle and 25 cycle converting units in large capacities, is not enough to attract any particular attention. Thus the use of the commutating poles has been of advantage principally in allowing higher speeds, with consequent better characteristics in general.

The modifications above described cover electrical defects principally. However, there were a number of other minor conditions in these earlier machines which might be considered as mechanical defects, or mechanical and electrical combined. These were found principally in the brushholder and commutator constructions, and in the materials in the commutator. On the higher voltage machines, in which a large number of commutator bars per pole was necessary, the thickness of each bar was, and still is, very small, and thus the proportion of thickness of mica between bars to the thickness of the bars themselves is a very considerable percent. On this account, it has been difficult to obtain, in many cases, a wear or abrasion of the mica equal to the so-called copper "wear," which, in reality, is more in the nature of slow burning than actual wear from friction. No matter how perfect the commutation may be in appearance, there is always a slight tendency to burn the face of the commutator by the current passing between the commutator and the brushes. This burning normally may be at an extremely slow rate, but if the mica does not wear down at the same rate, the result will be that, after a time, the mica lifts the brush surface away from contact with the copper, and thus an almost infinitesimal gap exists between the brush and the copper of the commutator. This gap then exaggerates the burning tendency, and the difficulty accentuates itself. The hardness and wearing quality of the mica must be such that it will always wear down as fast as the copper burns away, so that normal contact is maintained between the copper and the brush. Where the percentage of mica is high, and where the mica varies in hardness, as is liable to be the case in practice, it is difficult to avoid more or less tendency to high mica and consequent trouble. This trouble is also accentuated by high commutator peripheral speeds, as it is more difficult to maintain uniform contact between the brush face and the commutator. In consequence, in 60 cycle rotary converters in general, and in high voltages in particular, experience has shown that it is advisable to undercut the mica slightly, in order to avoid any tendency toward high mica, and also in order to be able to use brushes which contain some lubricant, such as graphite. It is obvious that where any considerable grinding action by the brushes is necessary to keep down the mica, such lubrication is not practicable to the same extent as where no grinding action is necessary. In consequence, on later types of 60 cycle converters, the commutator mica is usually undercut, thus allowing good contact to be maintained, and thus reducing any resultant burning action to the minimum. The true causes of the difficulty with high mica were not thoroughly appreciated in the older 60 cycle converters, and, in consequence, in many cases brushes of a hard, grinding character were used, with resulting increased losses and other disadvantages. Also, on some of the older machines, even with the much lower peripheral speeds than at present, the design and construction of commutators were not as nearly perfected as at present, and there was always more or less danger from unevenness, and other defects, which, while not showing in themselves any particularly harmful results, would very often show indirect harm by causing high mica, sparking, brush troubles, etc. Furthermore, in many of the earlier machines, the brushholders were not as rigid or as well suited for operation on high speed commutators as in present practice. In some cases the operating characteristics of the converter were greatly modified by simply changing the angle of inclination, or the brush pressure, etc. Brush chattering was not uncommon, and if there is anything which will surely cause bad commutators and commutation, it is severe chattering at the brushes, as this prevents good contact between the face of the carbon and the commutator face.

On many of the earlier machines the brushholders were not arranged with due regard to harmful results from incipient arcs between bars, or in the neighborhood of the brushholders and brushes. On sudden changes in load, or partial short-circuits, or even in normal operation in those cases where the maximum voltage between bars is unduly high, the not uncommon "ring-fire" around the commutator, due to burning of the carbon or graphite deposited on the mica or between bars, may develop into small arcs, with consequent vaporization of copper, the resultant vapor being a good conductor. If the brushholder or other parts are in close proximity to the point where such small arcs may form, the conducting vapor may bridge across from the commutator face to the adjacent parts, where there is any considerable difference of potential between them, and may develop real arcs or flashes which are of a destructive nature, possibly necessitating the shutting down of the machine until the commutator can be smoothed up. In many of the older machines, with their very small distances between the brushholders, generally crowded conditions, and high voltages per bar, such arcs were much more liable to occur than in the modern machines.

In the development of the 60 cycle rotary converter, there were other conditions beside commutation, flashing, etc., which had to be taken into account. The rotary converter is a synchronous machine, and must follow rigidly in step with its source of e.m.f. supply, or there will be difficulties in the operation. The early converters, in many cases, were operated from generators driven by slow-speed reciprocating engines, which did not run at uniform rotative speed, there being pronounced periodic speed fluctuations during each revolution. In some cases this condition was so bad that the generators in the power house would not operate properly in parallel. As the engines and generators varied in speed periodically, obviously the frequency of the electric circuit varied to the same extent, and any synchronous apparatus operated on such a system would also have to vary in speed to the same extent, if the conditions were such that the machine should follow the supply system, as is the case in rotary converters. If the converter did not follow rigidly, it would periodically either "under-run" or "overrun." This action is called hunting, and it was very serious at some of the early plants. Not infrequently the generators at the power house would not hold a rigid relation to each other, and hunted badly.

There are causes of hunting, other than variations in speed of the prime mover or generating unit, but usually these have been of secondary importance, and will not be considered further. The action of hunting, with variations in speed of the generator, may be explained briefly as follows: The converter generates an alternating e.m.f. wave similar to that of the generating or supply system, but in opposition, or as a counter e.m.f. If the generator momentarily runs faster, then its e.m.f. will be ahead of that of the converter. A motor current flows, tending to raise the speed of the converter to that of the generator. If the generator now drops back in speed, its e.m.f. wave drops back, and the converter tends to deliver current to the generating system, thus tending to slow the converter speed down to that of the generator. The action in the converter is therefore one which tends to speed it up or slow it down to follow the generator. This action of the converter, acting alternately as a motor or as a generator, is what constitutes hunting. Usually this action of following the generator speed is not a serious one, as a relatively small current may produce the necessary accelerating or retarding action. The difficulty is that the converter may over-run; that is, it may speed up too much or drop back too much, and thus have an increased motor or generator action. In other words, this accelerating or retarding action may exaggerate the swinging effect, just as in the case of a swinging pendulum, where a very slight force, if timed just right, may gradually increase the swing of the pendulum. In those cases in the early converters where hunting was most severe, the periodic speed changes in the generating system were usually timed just right to cause the converters to over-run, and thus exaggerate the hunting action.

The direct result of this hunting was visible in bad operation at the commutator. In the normal rotary converter, when running properly in synchronism, there is practically no armature reaction in the armature winding, such as is found in direct-current machines, for the alternating current supplied to the armature winding is in opposition to, and practically neutralizes, the magnetizing effect due to the direct current delivered. Therefore, as far as reactions on the field are concerned, the converter is quite different from a direct-current machine, and at full load the armature has very little more effect on the field than at no load. However, when the converter is hunting, the current due to the hunting action above described is not balanced by the direct current delivered, so that this current acts like that in a straight alternating or direct-current machine, and sets up magnetic fluxes in the interpolar space, and under the edges of the poles, which are harmful in character. These fluxes create bad commutating conditions by reason of the armature coils under the brushes being short-circuited in a periodically varying magnetic field, which is not the case when the converter is not hunting. Therefore, as a converter hunts, there is usually periodic sparking at the brushes, which is in time with the periodic "beat" which usually can be heard in a machine when it hunts. This sparking will get more and more severe as the converter hunts more, until it may become so bad that the machine flashes over. This hunting in some of the earlier machines was a very puzzling phenomenon, and it was not until its nature and cause were determined that an effective remedy was applied. The corrective now universally applied consists in the use of copper danpers, or "cage windings," in the field pole faces of the converters. It is not within the province of this paper to explain the action of these dampers, but it may simply be said that they exert, to a certain extent, a braking action on the over-running action of the converter, and also they damp out the field distortions due to hunting, such distortions materially exaggerating the hunting action. The dampers thus reduce one source of accentuation of the hunting, and exert a braking action to overcome the effects of the others. Such dampers were used early on 60 cycle converters, but in comparatively crude forms. Moreover, the angular variations in speed with 60 cycle generating units, were usually greater in degree per electrical cycle, than in 25 cycle machines, due to the much larger number of poles, and this made the hunting tendencies of the converters much greater, and the damping problem correspondingly more difficult than in 25 cycle machines. In consequence, 60 cycle converters should have had more damping action than 25 cycle machines, while, on the contrary, they actually had much less. The 60 cycle converter was, therefore, considered a much more delicate machine as regards hunting, than its 25 cycle brother, and yet the fault was really in the generating plant in many cases.

The advent of the 60 cycle turbo-generating plants have been a large item in the successful development of the later type of 60 cycle converters. The problem of angular variation in speed of the prime mover has disappeared, and therefore the dampers on modern 60 cycle converters have to take care of only those secondary causes of hunting, which were present in the old conditions, but were masked by the much greater cause in the generating conditions. Also, with the newer high-speed converters, with their relatively wider poles, it is practicable to add many more damper bars per pole than in the older machines, and, in fact, with the later machines the problem of hunting is rarely encountered. However, a new problem in connection with hunting has come up in connection with the advent of the commutating pole, both in 25 and 60 cycles. In the commutating pole generator, the ampere-turns in each commutating pole coil are sufficient to not only neutralize the entire magnetizing force of the armature winding per pole, but to also furnish an excess flux for commutating. In the commutating pole converter there is normally but little resultant magnetizing effect in the armature winding, due to the alternating and direct currents being normally in opposition, and therefore the commutating pole winding must only be strong enough to neutralize the very small resultant armature reaction, and give, in addition, a magnetic flux sufficient for commutation. In consequence, the ampere-turns of the commutating pole winding may be only 30 to 40 percent of the total armature ampere-turns, considered as in an alternating or direct-current machine, whereas in an alternating or direct-current generator the commutating pole winding is usually at least 125 percent of the armature ampere-turns. Therefore, the rotary converter with its 30 to 40 percent commutating pole ampere-turns, instead of 125 percent, cannot act as a generator or motor with good commutation, as its commutating pole strength is then much less than required. As a generator or motor, the armature reaction may not only overpower the commutating pole winding, but may set up a strong magnetic flux in the wrong direction. The commutating conditions may this become much worse than if the commutating pole were present. Therefore, the commutating pole converter, when acting as a generator or motor, is a much worse machine than if the commutating pole itself were omitted. Herein lies a source of possible trouble with commutating pole converters. In case there is hunting, the armature will act alternately as a generator and motor, and, under such conditions, the magnetizing force of the armature may be such that it will demagnetize the commutating pole, or even reverse the flux under it, so that the machine acts in the same way as if it were operating with the current reversed in the commutating pole winding, which would obviously give very bad commutating conditions Therefore, when the commutating pole converter hunts, it represents a worse condition than when a non-commutating pole machine hunts to an equal extent. In consequence, with commutating pole machines, it is very important to suppress any hunting tendency, and this, in general, requires somewhat better damping conditions than in the non-commutating pole machine. Therefore, although improved conditions of generation, etc., have eased up on the damper requirements, yet the necessities of the commutating poles have made the damper requirements more rigid. In some cases, this has led to a very curious situation. It is well known that the commutating pole, whether on a direct-current machine or on a converter, should not have any closed conducting circuit around it, as such a closed circuit acts as a secondary or opposing circuit in case of sudden change of load, preventing the commutating pole flux from rising or falling in step with changes in load. Therefore, from the standpoint of commutating pole construction, there should be no closed circuit surrounding the commutating pole itself. However, from the standpoint of the best arrangement of the damper to prevent hunting, a complete cage winding, tying all the poles together, as shown in Fig. 3, is, in general, the most economical and effective. But such a closed winding forms a rather effective closed secondary circuit around the commutating pole. One would therefore assume that it is inadvisable to close this damper circuit around the commutating pole, and that a break at *a* or *b*, for instance, would be an improvement. However, in some instances, experience has shown that the improvement in the damping action as a whole, in preventing hunting, by tying the windings together at *a* and *b*, more than over-balances the harmful effects of the closed secondary circuit around the commutating pole, caused by the closed damper winding. This is not necessary always the case, the results depending upon individual and local conditions, to some extent. The same damping effect as tying together at *a* and *b* might be obtained theoretically by special proportioning of the damper on each pole, but in some cases, especially on 60 cycle machines, space requirements do not permit such proportioning of the damper, so that it may prove better to tie the dampers together at *a* and *b*.

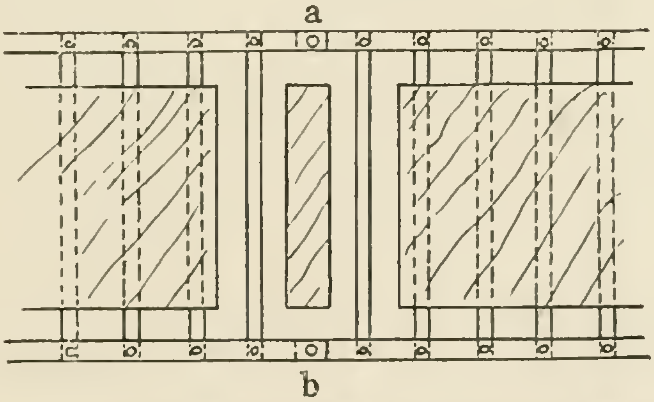

FIG. 3—CAGE WINDING FOR COMMUTATING POLE MACHINE

A new condition also developed in connection with self-starting commutating pole converters. In the older 60 cycle converters, starting motors were rather commonly used, due, not to the inability of the converter to start itself, but to the effect of the large starting current upon the relatively small generating plants of those days. Later practice tends strongly toward self-starting, except in special cases. There are some very considerable advantages in this self-starting, and at the same time, there are some disadvantages, especially in the 60 cycle converters. The greatest advantage lies in the rapidity with which the converter can be started from rest and brought up to synchronism, together with the fact that no synchronizing devices are required. With the old starting motor, the machine had to be brought to synchronous speed and then connected in step. This was more difficult with 60 than with 25 cycles, and self-starting eliminates this trouble. On the other hand, while starting and accelerating, the converter is purely an induction motor of a rather crude sort, and will take a relatively large starting current—in some cases approximately full-load current from the line—and this current is at a very low power-factor; that is, at least 90 to 95 percent is purely wattless. When starting a large capacity converter, this will represent a relatively large inductive load thrown suddenly on the power plant.

However, the new condition which developed with the advent of commutating poles, lies in sparking, and not in the starting current. As the converter at start acts like an induction motor, it has a rotating magnetic field flux set up, which travels around the armature. The armature coils short-circuited by the brushes form secondaries to, or are cut by, this field, and therefore have relatively large e.m.f.'s set up in them, which develop large local currents. The e.m.f.'s set up in the short-circuited coils are usually somewhat greater in the 60 cycle than in 25 cycle converters, due primarily to the fact that there are usually fewer conductors in series for the normal voltage of the machine, and therefore the normal voltage per conductor is relatively higher than in the 25 cycle converter. In consequence, at start, assuming that similar voltages are applied for starting both 60 and 25 cycle machines, the relative voltage per conductor generated by the rotating field set up by the armature winding will also be higher in the 60 cycle converter. Also, the number of commutator bars covered by the brush will usually be greater on the 60 cycle converter. In consequence of these two conditions, the short-circuiting action of the brushes and the sparking will be worse on the 60 cycle converters, but it is liable to be excessive on all large machines.

With the advent of the commutating pole rotary converter, a still more difficult condition has been encountered in self-starting, namely, that the flux conditions in the zone of commutation of the short-circuited coils are materially higher than in the non-commutating pole machine. In the latter type, while the short-circuited coils cut an alternating flux and therefore have local currents set up in them, these coils, in commutating or reversing these currents, lie midway between the poles, and therefore in the region where the conditions of reversal are easiest. But in placing the commutating pole directly over the short-circuited coils, the conditions of reversal of the short-circuited current are made much more difficult during starting. In consequence, during starting and accelerating, the sparking conditions in the commutating pole converter, both for 60 and 25 cycles, are much worse than in the older non-commutating pole type. In fact, in the larger machines, the conditions are so bad that it has been found necessary to add brush lifting devices which will lift all the brushes but two, during starting and bringing up to speed. This is an added complication, but it is offset, to some extent, by the fact that, with the brushes lifted, there is no sparking at all, and therefore the commutator does not suffer at all during the operation of starting.

In the earlier 60 cycle converters, the question of variable voltage came up in connection with 250 to 300 volt machines. The general means of voltage variation in these machines was almost entirely by means of induction regulators, or step-by-step transformers. It is only in very recent years that the self-contained units, such as the synchronous booster converters, and the regulating pole type, have been brought forward. For 60 cycles, the synchronous booster appears to be the only really practical method, due largely to limitations in design and in space requirements. If commutating poles are to be used, then the regulating pole type of machine, with main and auxiliary poles, in addition to the commutating poles, requires a very crowded design of field, unless a larger pole pitch is chosen than in the synchronous booster machine, in which there are only the commutating and the main poles.

When synchronous boosters are used with commutating poles, the problem of proper adjustment of the commutating pole strength, with varying loads and voltages, comes in. This problem of adjustment is just as pronounced in 60, as in 25 cycle machines. Where the range of voltage is relatively small—say, never exceeding ten percent up or down—it is practicable to so proportion the commutating pole windings that, without any automatic or hand-adjusting devices, good commutation can be obtained over the whole working range. However, if materially higher voltages are needed, such as 15 to 20 percent up or down, practice indicates that some auxiliary device is required for adjusting the field strength automatically, or by hand, at the extreme condition, which appears to be at no load with maximum boost or buck. For this condition, an automatic device has been developed, which, when the main current falls to a relatively low value—say, one-fourth full load—automatically short-circuits that part of the commutating pole winding which is in series with the booster field. The same operation cuts into the circuit a resistance equivalent to the section of the winding cut out. This latter is a necessity, due to the fact that any variation of the resistance of the booster field circuit will vary the amount of boost or buck, and thus affect the main voltage of the machine. Any automatic device therefore should hold the resistance of the booster circuit constant. Such devices have been installed on a number of synchronous booster, commutating-pole machines. They can be located at the converter and, being purely automatic in their action, require no attention from the switchboard operator. As such a device operates only very infrequently, but at fairly regular intervals, such as once or twice a day, it is not liable to wear out due to excessive operation, nor to stick due to nonuse. Experience has shown that, except for extremely wide ranges in direct-current voltage, only one step is needed in such an automatic device.

Sixty cycle rotary converters are now being manufactured in relatively large capacities, such as 1 000, 1 500 and 2 000 kilowatts, for 270 volts with synchronous boosters, and up to 2 500 kilowatts, for higher voltages. Larger capacities, for either voltage, can be constructed without difficulty, and with as good performance as in the capacities mentioned.

The modern 60 cycle rotary converter for either 270 or 600 volts, is approaching very close to the 25 cycle converter in its general characteristics, such as efficiency, etc. In commutation, it can be fully equal to the 25 cycle machine. In general reliability, the modern machine is far ahead of the older types. This development of the 60 cycle converter, therefore, removes one of the most serious handicaps formerly encountered by the large 60 cycle generating systems.

LETTER WRITTEN TO URBAN

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One of the aims of the JOURNAL is to be a magazine of inspiration as well as a journal of engineering. Articles of the first type rarely can be made to order, but usually must be discovered. In the following pages is presented a discovery of the inspirational type which should be of value to all young engineers. This letter, while written for the guidance of a particular individual, is of fairly general interpretation. It was first called to our attention confidentially by a friend and, realizing that its perusal should be of great value to others, a request was made for permission to publish in the JOURNAL. The author has had a long experience both as chief engineer of one of the large manufacturing concerns and as an observer of young men as they have taken up active work after the completion of their preliminary training.—(ED.)

MY DEAR URBAN:—

As you have decided to spend part of the interval between school terms in an endeavor to obtain some experience by entering the employ of the Westinghouse Air Brake Company, I think it only fitting that I should write you a few words of advice.

First—I would impress upon you that loyalty is the first consideration and is as much to be striven for and prized as it is difficult to exhibit and obtain.

Second—It is important that you discover what your duties are and fulfill them to the utmost of your ability. To do this, you must become conversant with the rules of the Company and its organization, and the question as to whether they meet your views or not is immaterial, since it has a right to decide what these shall be, leaving to you the right to leave the Company if you cannot conform to them.

Courtesy and tact in all your dealings with your superiors and fellow-employees are qualities greatly to be desired. In fact, without these, much of your opportunity to render good service and to obtain the reward for capable endeavor will be curtailed.

A pleasant demeanor will do much to make your association with the Company agreeable and beneficial, both to yourself and to all with whom you come in contact.

Integrity, both in fact and purpose, is absolutely essential if you are to raise and maintain yourself above the average level, as well as for your own peace of mind and for fearlessness in the assertion and maintenance of any position you may assume.

Accuracy should be one of your most important considerations and this will be impressed upon you when you reflect that there are usually many ways that a thing may go wrong, or be wrong, to one way that is right. Therefore, in analyzing, check yourself often enough to be sure that you have considered to the best of your ability all the factors involved and their relations to what you are considering both in its parts and as a whole. This is important whether you are making an examination of the subject either analytically, synthetically or mathematically, and I know of no better way for you to assure yourself of accuracy than the one followed by myself; namely, after having assured myself subjectively that I am right, I attempt to do this objectively, that is to my associates, before I put it to the crucial test—by crucial test, I mean before I am willing to risk it for endorsement or condemnation to those whose duty it is to pass final judgment.

Another good method is to cultivate intuitive reasoning in the matter, that is, does your conclusion conform to common sense and physical law? If you doubt this, obviously, a review of the whole question is incumbent upon you. For example, if your solution of a problem demonstrated that you would get something for nothing, you would know prima facie that there was an error somewhere, as this is contrary to nature and would involve a miracle. What I say later on, regarding greater and lesser forces is my key to the cultivation of intuitive reasoning. In this connection I would ask you to reflect upon the fact that when men leave college they are to all intents and purposes equal as far as accumulated knowledge is concerned, but, in practice, you will find but few who get material results from this knowledge, largely because they are not accurate in its employment.

Obedience to orders or instructions, it is hardly necessary to mention, is especially incumbent upon you and the name of being a "good soldier" is something I hope will soon be yours. The reason for orders or instructions may not, in fact, will not, always be clear to you and, therefore, you may be apt to look upon them as unreasonable, or even foolish, but remember that as compared with your superiors, you see only "through a glass darkly;" that these orders and instructions may be, and probably are, only links in a very long chain and that policies are much broader and cover a scope inconceivable to you at the moment. As you travel up the hill side the horizon will widen out and many things will appear to you that were hidden while you were in the valley. In many cases the good and wise policies of a concern have been defeated of their full attainment for lack of full-hearted obedience and coöperation by those who constitute it. The whole is made up of parts and each part or unit must perform its full duty if the attainment of purpose and proper efficiency is to be accomplished.

Never betray any confidences that are entrusted to you. Refuse confidences that you cannot loyally retain, for it is better not to receive the confidences than not to be sure that you can retain them without being disloyal to some one else. Never force your confidence upon any one who will be embarrassed by its possession, for generally a confidence becomes a three-cornered affair and does much to endanger the best friendships. Therefore, while it is well to be friendly and make friends, in the general acceptance of the term, with all self-respecting men, it is unwise to have more than one who has your confidence, or is your team-mate. Even here use extreme care as to what you give or receive.

Coöperation is a duty you owe both to yourself and to your fellows. Self-seeking generally defeats its purpose, for few can go it alone, and he who refuses to help others will generally be forced to do this, as only he who gives shall receive. Not that you are sure to receive if you give, but you are very likely to; while if you give not, you are sure not to receive. The only good reason for not helping the other fellow out is that you cannot do so without greater loss or neglect of your own duties. Coöperation, or team work, is a great asset to a concern, for in unity of action there are great results.

You must expect to meet all that is good and all that is bad in human nature, particularly if you forge ahead, for it is only then that you are worth while as a mark—as a mark for adulation and a mark for envy and their categories. It is here that you will meet your supreme test, for you may be lulled to sleep by the one and rattled to destruction by the other. The latter is not the bite of the lion, but of an insect, irritating and annoying, it is true, but can do you no real harm without your consent.

Cultivate a cheerful acceptance of the disagreeable, annoying, irritating and difficult actions and circumstances necessarily attendant upon any position of life, but which more particularly marshal themselves against one marching under the banner "Excelsior." Not only is anger or complaint against these unavailing to yourself, but is gratifying both to those who would prevent your success and to those who would hold you down to their own level. As well might a soldier complain of the bullets of the battlefield as one complain of obstacles, difficulties and annoyances in the field of business. Rather be glad when difficulties and annoyances present themselves to you, for they furnish both the opportunity and incentive for you to measure up to the full stature of a man. As there are but a few who appreciate these things as an opportunity and incentive, the mere fact that you know their value and have the grit to encounter them in the proper spirit, will give you an advantage very early in your career. The greatest measure of success lies in a more minute subdivision of things done, and in the undone and difficult things of life. These in turn involve the whole gamut of ability, tolerance, ingenuity and tact, and he who would explore these mines for their hidden benefits and riches must be prepared to meet all that imagination can conceive of human perverseness.

I desire to call your attention particularly to the difference between accumulated knowledge and the application thereof. Do not think because you have attained to a large degree of technical knowledge that you have learned how it should be applied to the practical details of a life's work, or that theory can take the place of practical experience, or that it, prima facie, is evidence of a "level head." It has been said that theory is the bed rock and practice the capstone. As a matter of fact, theory and practice coalesce and become one and the same thing when all the factors involved are taken into account. The reason why so many things fail that are supposedly correctly worked out theoretically, is that conditions and details that occur only in practical use are left out of consideration. When these are not known a margin should be left for their probability and "a good engineer" is not he who knows the most, but the man who can meet the conditions the best; in other words, it is in the application of knowledge and common sense that the greatest results lie and from which successful achievement results.

There are but few, if any, things you will find that are all right or all wrong; generally, it is better to consider everything on a basis of good or bad which can measurably be determined by casting a balance. Therefore, in all your investigations, discussions or debates, it is essential that you should discover, if possible, the angle or point of view, that for the moment is the other fellow's controlling influence. When this is discovered, it is obvious that the analysis, or discussion, turns from the proposition or device, to the point of view. This must be agreed upon by both before culminating progress can be made. Assertions only have force with those who accept them. Therefore, try to get your controversialist back to some point upon which you can agree; in which case, it may be found that his point of view is not even on the line when the vital issue is reached.

Be careful not to assume a burden of proof or to make assertions that cover more than is required for the particular case. In fact, you should be continually on the qui vive to shift the proving business to the other fellow. I know of no better way to convince the other fellow that he is wrong, at least in some degree, than to let him try to prove his own propositions. Strange as it may seem, questions, rather than assertions, contribute materially to this end. Be careful to use particular propositions rather than universal ones when a universal one is neither material nor provable, for you must know that one exception is as good as a thousand to disprove a universal proposition. In this connection be wary of the adjective and adverb fiend, for while these terms have an impression value to the emotional or unwary, they are generally used as special pleaders or in the place of evidence or proof. Watching for their appearance in the other fellow should and will teach you to avoid them yourself except when you are convinced that you have a warrant for their use.

Avoid entanglements. Make none until you have counted the cost, then conform to them whatever may be the sacrifice until they honorably expire. If you make the determination to fulfill them at whatever cost, it will be equivalent to a determination to be very careful in assuming them, which is what I desire. Mind, I say, careful, for I do not want you to be always waiting for a sure thing, as this life to be successful must be conducted on the basis of reasonable probability.

Be careful in your acceptance or choice of companions or friends. Associate only with those who in word and deed show that to them life has a purpose beyond selfish gratification and mere incumbency of the earth. Subject yourself to the influence of the good, the thoughtful, the energetic and the progressive. Avoid or repel the influence of the shiftless, the unthinking, and those who by nature or inclination remain stationary, and who because of this would hold others to their level. Heed not their persuasion, ridicule, their taunts or sophistries, for they are not seeking your good; rather by an accretion of their numbers they are desiring a plausible justification for their condition and inertia.

Avoid debt as you would a pestilence. By debt, I mean assuming obligations beyond your means, or that you cannot with reasonable certainty expect to repay. This kind of debt is equivalent to giving a mortgage on your honor, your activities and your sustenance. In money matters, as in the other things I have advised, it is wise to always have a reserve. But even at the expense of this, do not stunt your life or fail to realize that its largeness will be greatly increased by using all that nature and art offer you according to your means.

Save some money from every dollar you earn, because such a policy makes for independence of action—it makes for power and influence. The despised (?) dollar has been maligned too long. I believe I could write a volume on the poetry and inspiration of the dollar. And there is a practical contentment and a moral courage in a bank account that a man can acquire in no other way. At the same time do not forget that generosity and charity are virtues. Therefore, be generous to your friends and charitable to all whose want and condition make you to some extent their servant or keeper. This will at times call for sacrifice on your part, but to be a whole man you must not shirk it.

Do not forget in thinking of your duty and responsibility to others that God holds you responsible for yourself and expects development in you at least equal to that which you would insure in others. Self-neglect is as bad or worse than the neglect of others, for its example may entirely defeat the object for which it is done.

Avoid extremes, for remember that extremes meet. A piece of iron extremely cold will burn you just as quickly and severely as a piece of iron extremely hot, and paradoxical as it may seem, the farther away from a thing you may go in one direction, the nearer you are approaching it in the other. It takes a lively imagination to picture extremes, but you will profit by cultivating the habit.

Do not be too ready to endorse or condemn anything from the mere abstract supposition that it is either right or wrong, for this is largely a question of custom, environment, and the opinion of a number formulated into a law, and is different in different places and under different times. Rather take also into consideration with this, whether the proposal or the outcome will be great or small, for most things are considered right when they become great and wrong when they become small, and it is not always clear what they will be at the start. Consequences, as far as human progress is concerned, are what determine quality, even though these consequences change from time to time, and, therefore, you should at all times consider whether a thing is right per se or is only made so. If the latter, it has no standing in fact as compared with another thing which may be greater.

I am not asking you to, Don Quixote fashion, charge every wind-mill that you may chance to espy, but rather to consider carefully all sides of a given question and not to condemn until you are reasonably sure that you have a substitute which will change things for the better, then proceed not to compel, but to educate others into the adoption of a more progressive course.

Do not be discouraged because others do not rush with embracing arms to accept your convictions, for, even though you may be right, it may be necessary for them to climb the same paths to the mountain top before they reach your conclusion and you will find that they can be induced to travel this path where they cannot be compelled. Discouragement in the demeanor of one who would lead is a decided handicap, and mind you, your only course is to lead, to convince, to persuade, for there are but few who possess the individual power to make their will a law.

Whatever may be the abstract theory, or conventionally stated platitudes and requirements regarding improvements or changes, in practice you will find that incredulity, doubt, opposition and a clinging nature have to be encountered and you will be wise to discount these at the beginning. If you begin early it will become a characteristic to a much greater degree than with myself, though I flatter myself that few men would have met these things with quite as lamb-like a disposition as I have. In all the matters discoursed upon in this letter I have had practical experience, but in none so much as in this one, for I cannot recall a single innovation that I have submitted but what has had to find its way through what I have mentioned, and even though more care is now exercised by my critics, so firmly imbedded in human nature are these propensities that the same ordeal has still to be faced. Perhaps it is wise that it is so, for it will make you exceedingly careful of your premises and conclusions. Its chief evil is the impatience aroused because of delays which are really unnecessary, and, in addition, one is provoked that time and energy which could be devoted to further accomplishment, are exhausted by such barriers.

Also, it is likely to happen that you will find yourself in the same predicament as others at times and may want to adroitly dodge the issue rather than to admit that you "do not know." For many, this is the safe side, as it involves but little risk and no responsibility—its aim is self-preservation rather than another's destruction. It is a fine substitute for discernment and dodges the question of competency, as well as passing for wisdom of a certain kind. I fear, you may some times be tempted to shelter yourself within this magic circle; I hope, however, that you will resist the temptation to use these ordinary and, to the informed, transparent subterfuges, and candidly admit, when called upon to judge of matters of which you have not made sufficient and special study, your incompetency, with the statement that this should not be counted against the thing being considered. This will create confidence in you, for remember that this only applies to particular cases and not to your ability or intelligence in general or to matters which are special to you, for in these I am sure you will obtain a competency that will create as large a confidence on the other side. By many it is regarded as almost a crime for one to proclaim that he can supply something which others have not yet discovered they need, notwithstanding that its benefits in wealth and general good may be vast; therefore, while I desire you to maintain a sanguine spirit, it should not be from the conviction that if you make two blades of grass grow where one has grown before that it will be accepted with a brass band of acclamation, but rather from the determination not to be discouraged because you cannot at once compel all interests and opinions to subserve themselves to what you know to be the merits of your case.

I do not know of any single thing that I can inculcate that will be of greater service to you than to cultivate an expectation of these things, for then you will look upon them as ubiquitous, if not desirable, evils, and will meet them in a spirit which in itself will be of the greatest possible assistance in attaining success. This particular thing, or what

I call the human end of my work, is a far greater disturber of my poise than any of the problems or other troubles connected with the mechanical end, and I want you to so cultivate your nature and manner that you may meet these as serenely as you do any other problems or difficulties.

While it is a rule that one should meet his opponent with the kind of weapons he employs, I here offer you a better one, namely, meet him with superior ones, if possible. If he should endeavor to meet you with those that are unworthy, do not cast aside those of honor and manliness and pick up those of dishonor and deceit, for soon he will find that there is a flaw in his steel and that his bullets are of wax. Generally, the one who uses unworthy weapons, either mental or physical, should not be met in the open with weapons at all, and I have found that all that is necessary to vanquish him is to set a trap. Prefer defeat to dishonor, and lose if you cannot win fairly. For the inevitable combat between the doer and the "stand-patter," you must fortify yourself with a full knowledge of your subject, and become familiar with all the arts and artifices of the critic and preferment hunter as well as all that is necessary to convince and persuade the honest doubter or skeptic. Always be able and prepared "to show a reason for the faith that is in you." Tolerance to the limit of human endurance I urge upon you, for one of the first things you will be charged with is intolerance and a desire to ride rough-shod over the inherited and acquired opinions of your opponents.

Avoid excess of every kind, for there is no evading the promise to pay. Involved in any transaction pertaining to your physical or mental nature is a debt which may not be collectable on a sight draft, but never forget that deferred payments inevitably mature and when the demand is made, payment can neither be evaded nor postponed. Whenever fatigued, rest in some form should be welcomed, but do not mistake laziness for fatigue. Remember that every man is as lazy as he dares to be, and the value of your purpose is the measure of the dare quantity to you Still this should not be interpreted to mean that you should work up to the limit either mentally or physically; quite the contrary, for you should always have something in reserve, if possible, only put out all you have when less will not win.

While trying to impress you, as I do later on, with the fact that analogy and inference of outside subjects are what determine, even though we may be unaware of it, the course of our life, I would not have you forget that self-analysis is fully as important as that of other and outside things.

Most of all I want your life to be governed by the conviction that God is, and that He rules the world. Once convinced of this and you will know that there is a reason for all things; that in spite of the limitations of our finite being which prevent our understanding many things, there is a purpose in the existence of the world and the present state of its progress towards the ultimate. It will also place in your possession the key to that great secret, apparently self-evident and yet hidden in its fullness of meaning from the many, viz. that the greater force will overcome the lesser, which is the law of all that takes place. To discover on which side it exists is your problem; for in it is the solution of all the enigmas you will encounter and the achievements you desire to accomplish. In this are involved all the physical laws, as well as those which determine your spiritual well-being. A full appreciation of this will enable you, when dealing with engineering matters, to determine with assurance what result will be obtained under a given set of conditions. While I always expect you to welcome a scepticism which says "let us test it," still I desire you to rise above the mediocre which fails to see that doubt is synonymous with incompetency, no matter whether justified or not, and that a recommendation limited to "let us try it," is nothing more than the ink of the cuttle-fish which serves to obscure incapacity and ignorance, but in no sense proclaims a knowledge of the direction of the greater force.

I want you to realize that there is great virtue in (progressive) conservatism, but to avoid appropriating this designation to conceal fear and ignorance. Discover if you can the greater force, then proclaim your judgment and be strong.

Next, a study and analysis of human nature must not be neglected. Every human being that comes under your observation ,and with whom you come in contact, should be carefully scrutinized, and, wherever important, an endeavor should be made to discover his "Ruling Passion." Never forget that whenever two people are together, there are at least six in the circle, for as Holmes says, "There is the other as you think he is, as he thinks he is, and as he really is, and yourself likewise." This one fact explains in a large measure the many angles and points of view which are responsible for the various opinions on even the most elementary subjects and circumstances of life.

Always keep in mind that men are more alike than they are different and thus you will never forget that in these few differences lie those things which make the able man, or the converse. A recognition and remembrance of this one thing takes you far into the study of human nature; that is, its incentives. its motives and its incongruities.

Further, I would call your attention particularly to the necessity of making distinctions between matters that are important and unimportant to your purpose in life, or to the matter in hand; also, you should carefully distinguish between things that are clear and comprehensive and those whcih are vague, equivocal and ambiguous. Distinguish also carefully between conciseness and redundancy, both in your spoken and written discourse. While conciseness is to be desired for many reasons, you will usually find that in conciseness there is grave danger, for generally it is so incomplete as to be misleading, or is intentionally concise in order to evade or deceive. On the other hand, redundancy is objectionable in that it requires, at least on its face, more time than will be given to it by your audience or to its perusal. Therefore, you should study to state clearly what you intend to convey with just sufficient wording to insure a correct understanding and to prevent its being misleading, misconstrued, or misapplied. One extreme is perhaps as bad as the other. Still I want to warn you not to expect your judge (that is, the one to whom you submit your proposition for judgment) to know as much as you do about the matter, since this is hardly to be expected if you have been making a study for a development of anything beyond that which is ordinarily known; therefore ,insufficiency of evidence is likely to defeat your purpose.

The sooner you learn that he who would upset the existing state of things must assume the burden of proof, the sooner you will have a mortgage upon the accomplishment of your purpose, and acquire a disposition to meet all opposition with a fascinating smile and a persuasive manner.

It is well to always assume that those with whom you come in contact are honest and sincere in word and intent, and this assumption should be conducive to both tolerance and courtesy on your part. Still you must never lose sight of the fact that neither of these things can stand for either right or competency, and therefore should form no part of your premises in reaching a conclusion. Be careful to divide with a sharp line all things emotional and intellectual, for you must not let your emotions run away with your judgment or sidetrack your intellect. Nor does it follow that when you are convinced, you should also be persuaded, for often many things must be considered before your conviction should become an overt act. On the other hand, do not be satisfied with having convinced another that what you propose or purpose is right or of value, for before it can become so, he must be persuaded to give it life and a real opportunity.

With all the foregoing observed, a purpose in life must be determined upon, otherwise you have an accompaniment without the soloist—a company of soldiers without a leader—a ship without a rudder. Imagine to yourself a ship at sea without a course laid out, or a port in view, and you have a life without a purpose. Therefore, I urge you to use all diligence in determining what this shall be and, once determined, it should be followed with persistency and perseverance, for it is not so much what the purpose covers as a purpose itself which is important, since there are but few, if any, things that cannot be obtained if all one's energies are bent in that direction. There are no Alps between consecration and achievement. Concentration, the invincible, naturally follows consecration, in fact, they go hand in hand and they will almost always prevail. Do not let too many things draw on your energies. They interfere with concentration and weaken your efforts by dividing them too much. A proper diversity of interest and action is good—even necessary, but too few begin early to put the whole force of their mental and physical facilities upon a given project or performance to its solution or completion in the very best possible way. Take advantage of this neglect and lack of effort by doing your best which will take you beyond their pace. Play life, live life—work-a-day things—just as you play football—you know how here the fittest goes to the front.

With reference now to the immediate present, I desire that you thoroughly ground yourself in the principles of logic, that is, the art and science of reasoning. By art, I mean the manner of it, both inwardly and outwardly, and by science, the matter employed. I want you to persuade yourself to always ask the question "Why?" and "Why is it as it is?" This followed up by the utilization of your mental powers to obtain an answer will help you over the road of your purpose much more easily and quickly than anything else that I know. Next, ask always "if 'this' is necessarily so from what I know or the information furnished?" If you cannot see clearly that the conclusion offered must of necessity follow from the matter, or information before you, then defer conviction or action until you are sure that at least strong probability is on the side of your act. A good rule to follow is, if an assertion is not qualified, to inquire why it is not, and if it is, why it is. You will usually find in the answer to either of these that there is a great deal more involved than appears on the surface.

Use those things which you can see or apprehend through the senses only as a means to an end, for the senses apprehend only the effect, the cause being receivable only through the mind, and this only by the use of all the intellectual faculties. Sight and the other senses should be considered only as preceptors and conveyors of outward things to the mind where they must receive the final challenge as to verity. Remember the greatest liars and deceivers are the sensations; therefore, be on your guard at all times that the effect may not be mistaken for the cause. Even when you are convinced that this or that is a fact, ask yourself "What of it," for after all, this is the acid test to which you must put all your reasoning. When performing this process of analysis or inference, ask yourself these four questions. Is this a fact? If so, what relation does it bear to the matter under consideration? In this consideration, is there any equivocation involved? and after having satisfied yourself with regard to those, ask the further question of whether or not there is sufficient reason for doing or not doing what is contemplated.

In reaching conclusions, be careful that they are reached by the processes of observation, hypothesis, deductive and inductive analysis, and then verify to the best degree possible under the circumstances. Above all remember that no statement, assertion or conclusion has any scientific validity until it is impersonal. Do not be deceived in this connection by dogmas that owe their authority only to an arbitrary power, for while they may have for the time being all the force of a scientific fact, their existence is purely ephemeral and dies with the snuffing of the power of their sponsor. An encounter with one of these animals requires the charmed life of the St. George who encountered the dragon, and only time, patience and a demonstration that interests will be better served, will bring you the requisite enchantment for a victory. Upon logic, whether we know it or not, we must rely; even in walking one is something of an athlete, so all who reason are logicians—the difference, as in athletics, being one of degree, not of kind—then, since all of the foregoing involve reasoning of a very high order for their proper evolution into your life and character, I particularly desire and request that you arduously and assiduously devote your time to an understanding of the wonderful powers possessed, but often undeveloped, in the mind of man.

While the foregoing may seem to inculcate upon you those things which make for what we may call "material success," they go much farther, for one could hardly succeed by the exercise of the qualities I have laid down without also attaining that success which is more than personal—a success that will give you power and influence which will be used for the well-being and betterment of mankind—a success that when you come down to the River will enable you to look back and feel the assurance of a life that fundamentally has been lived for the best.

My conviction that this advice is essential to your welfare and success comes not from supposition, either by myself or others, but by experience, for I have benefited by the observance of some and suffered by the breach of others until the effect taught me the wisdom of searching for and adopting a new rule of conduct—new only to me, for the experience of all men in all ages has proved that what is here set before you is as fixed as nature's laws in the development of a well-ordered and successful life. In our ignorance, egotism and pride, we begin by assuming that we are exempt, or immune, or in some manner superior to them, but in the end we are compelled to succumb and acknowledge them, many in sorrow and regret because of failure; others in thankfulness that they learned and observed them ere it was too late; a few by profiting by the experience and advice of others whose love and interest induced them to sound a warning of danger ahead and to point out a safe and sure course to follow. Be one of the latter—not by advice alone but by close observance of the standing of those who follow these rules and of those who do not, for I give you these rules of conduct not to be followed in blind faith, but rather that you may know of them, being content to rest in the assurance that your common sense will not permit you to ignore danger when forewarned, and that your strong desire to be a true man and to live a creditable and beneficial life will cause you not to reject without reason or consideration any advice or rule that promises assistance to this end.

I hope you will pardon the length of this letter, which I feel sure you will do when you consider that it is an endeavor to point out to you what in my judgment and in my love for you I consider the principles that should govern your whole life and the procedure you should follow. An effort on your part to recapitulate by a review and condensation will be profitable in many ways, not the least of which will be the demonstration that life is a broad proposition after all.

Trusting that my greatest desires for your happiness and success in life will be realized, I remain, Your loving father,

....

THE BEET SUGAR INDUSTRY

WIRT S. SCOTT

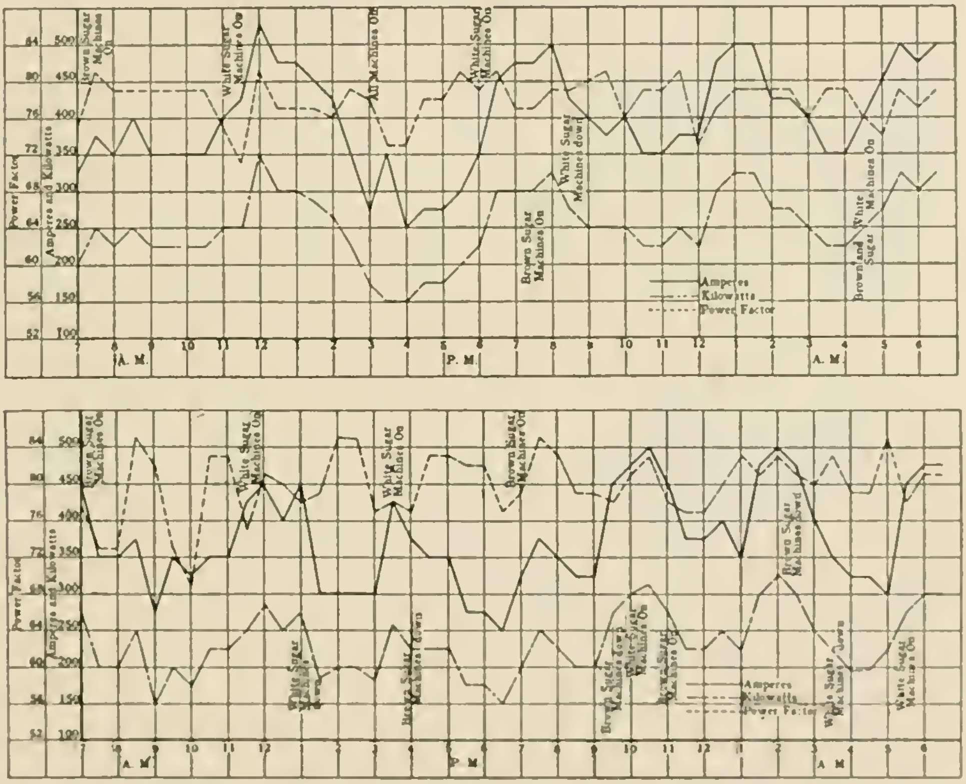
A BEET SUGAR factory is operated for but a comparatively short period each year, the exact length of time depending upon its location, as the beets must be obtained within a small radius from the plant. The period of operation is termed in beet sugar parlance the "campaign," and varies from two to three and one-half months, during which period the factory operates twenty-four hours a day continuously until the supply of beets has become exhausted.

The field for the development of electric power in sugar factories is tremendous. However, a statement is usually made at the factory that it is doubtful if any advantages can be obtained by electric drive, since:—*a*—a large quantity of steam is required in the cooking process; hence it is very economical to use non-condensing engines, obtaining power at a very small cost; *b*—as the operation is continuous day and night during the campaign period, electric power would be too unreliable; *c*—the load factor is practically unity, hence there would be no advantage in individual or small group drive.

Once the conditions of operation are thoroughly understood, these statements will be seen to have very little weight. In general, they may be met as follows:—

a—A great loss of heat results by radiation from the steam pipes to and from the engine. The engines necessarily must be located with reference to the machines which are being driven, rather than with reference to the devices using the exhaust steam; hence much more steam must be generated than would be required if the reverse were true. By the use of a turbine operating against a back pressure of from 10 to 15 pounds, according to the particular plant, there will be practically no loss in heat from the boilers to the turbine, also the exhaust steam piping from the turbine may be run direct to the point where the steam is required.

b—While the general operation of the factory is continuous, barring accidents, day and night from two to three months per year, yet it is not more so than numerous other industries, such as cement, paper and steel mills, to which motors have been applied with great success. The machinery in a beet sugar factory is worked at its maximum productive capacity in order to use up the beets at the same rate at which they are being delivered, so as to avoid putrefaction and a loss of sugar contents. A shut down of but a few hours causes not only the customary losses resulting from decreased production with the same overhead and running expenses, but a loss of certain portions of the material in course of production, which has the effect of requiring a greater percentage of material to be handled for the amount of finished product obtained. To meet these conditions successfully, apparatus of the most reliable type must be used.

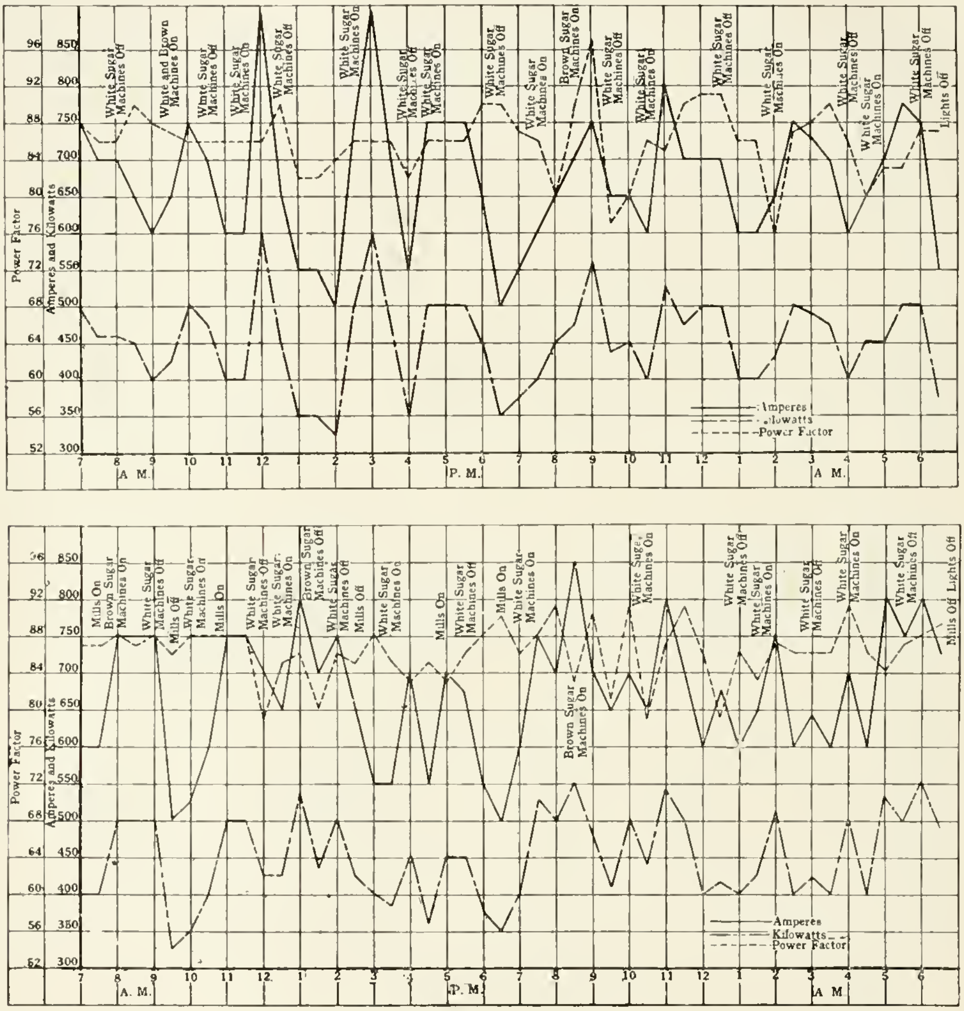


FIGS. 1 AND 2—LOAD CHARACTERISTICS OF THE HOLLY SUGAR CO. PLANT AT HUNTINGTON BEACH, CALIF., FOR SEPT. 16 AND SEPT. 17, 1911

OPERATING DATA

	Sept. 16, 1911	Sept. 17, 1911
Tons of beets sliced	773	846
Pounds of sugar bagged	185000	250505
Total kw-hrs. consumer	10140	10760
Average kw-hrs. consumed per hour	422	448
Kw-hrs. per ton of beets sliced	13.2	12.7
Kw-hrs. per ton of sugar bagged	109.5	85.8
Maximum kw demand	468	513
Minimum kw demand	338	318
Average kw demand	422	448
Average kw demand per ton of beets per 24 hrs	0.546	0.53

c—From data obtained from a complete electrically equipped sugar factory, the load factor, defined as the ratio of the average load to the capacity in motors installed, was slightly over 60 percent. The load curves, presented in Figs. 1 to 4, form additional proof that the load factor is far from unity. The load factor of this plant is, without doubt, higher than any operated by steam engines, as individual machines or machines in small groups can be shut down without interfering with the general process of manufacture. This is of special importance as the machines, as above stated, are operated at their maximum productive capacity and, therefore, require more attention, repairs, etc., than is required for the operation of the average machine. The fact that individual machines or small groups of machines can be stopped



FIGS. 3 AND 4—LOAD CHARACTERISTICS OF THE HOLLY SUGAR CO. PLANT AT HUNTINGTON BEACH, CALIF., FOR OCT. 16 AND OCT. 17, 1912

OPERATING DATA

	Oct. 16, 1912	Oct. 17, 1912
Tons of beets sliced	1112	1044
Pounds of sugar bagged	37440	323600
Total kw-hrs. consumed	10794	10778
Average kw-hrs. consumed per hour	450	449
Kw-hrs. per ton of beets sliced	9.7	10.3
Kw-hrs. per ton of sugar bagged	57.6	64.5
Maximum kw demand	550.	550.
Minimum kw demand	325.	325.
Average kw demand	450.	449.
Average kw demand per ton of beets per 24 hrs	0.405	0.43

for a short time without decreasing the output of the factory is one of the best arguments in favor of electric drive, as the net result is an increased output in sugar, this being the result all sugar companies are striving to accomplish.

In order to present a description of the process of making sugar from beets, which will give a fairly clear idea of the various stages of manufacture, each part of the process is briefly dealt with in the following paragraphs, regardless of whether or not that particular part requires motive power.

Beets which are harvested and allowed to stand, decompose more or less, with the result that their sugar contents gradually decrease; consequently arrangements must be made with the farmers for delivering the beets at stated intervals. The beets, as received, are dumped into bins from which they are conveyed to the factory as required, by means of a hydraulic conveyor. The storage bins are covered and are constructed with sides in the form of inclined planes so arranged that the beets are dropped into a stream of water with the least amount of manual labor. The hydraulic conveyor consists usually of a concrete ditch, about two feet wide and six feet deep, through which running water floats the beets to the factory. Waste water from the factory is used for this purpose, the bulk of which is obtained from the condensers. The flow of the beets is fairly rapid as the fall of the ditch is approximately 0.2 inch per foot of length. The water, being warm, removes a large portion of the dirt before the beets arrive at the washer. While this method is universally used it has the objection of causing the loss of a portion of the sugar in the beets. This loss will vary from two to five percent, depending upon the length of the time the beets remain in the water.

Beet Washer—The beets are received from the hydraulic conveyor and elevated to a beet washer by means of a spiral conveyor or a bucket wheel. Here the remaining dirt adhering to the beets is removed by revolving paddles which also propel the beets through the washer onto a conveyor, terminating at the beet elevator. The water from the beet washer is passed over a screen, which retains the particles of beets which have broken off from the main stalk. The washed beets are conveyed by an endless bucket conveyor to the top of the building, usually a distance of about 60 feet, and emptied into a hopper. Here they are weighed automatically and dropped into a second hopper, from which they are drawn off into the beet slicer.

The Beet Slicer consists of a rotary drum on the circumference of which knives are placed. The beets fall through a funnel on the side of this drum and are pressed against the sides. The slices thus obtained, called "cossettes," are "V" shaped, one-eighth of an inch thick, one-fourth of an inch wide, and of lengths varying from one to four inches. The cossettes may be dropped directly from the beet slicer into the diffusion batteries by means of chutes when the batteries are arranged in circular form under the slicer, or carried on belt conveyors when the batteries are arranged in rows.

The Diffusion Batteries consist of cylinderical tanks called "cells," each having a capacity of from two to four tons of sliced beets. The cossettes enter through an opening at the top and, after the sugar has been extracted, the pulp is discharged through an opening in the bottom. Usually from ten to fourteen of the cells are connected in series and termed a "battery." The extraction of the sugar is by the dialysis of the soluble constituents contained within the cells of the beets and is accomplished by passing hot water through the diffusion cells containing the sliced beets. The piping permits any cell to be by-passed while being cleaned or filled.

After the cossettes are placed within the cell, the cover is fastened down, and the cell placed in service by turning the juice from the cells which have previously been filled and placed in operation, into the cell just filled. The entering juice, having passed through the entire series of cells, is at its maximum density. Consequently on coming into contact with new beet material, having at that time its largest percentage in sugar, this material is reduced in amount depending upon the relative amount of sugar in the juice and in the beet. The time required for reducing beets containing 18 percent sugar to a pulp containing less than one-half of one percent sugar varies from one to one and one-quarter hours. After the sugar is removed from the beets, the pulp is dropped into a tank from which it is pumped into a silo, where it is allowed to ferment and is used for stock food, or it is pumped into a drying plant where it is dried and sacked, the dried product also being used for stock food.

The raw diffusion juice as it comes from the diffusion batteries is a pale-yellowish color which quickly turns dark on exposure to the air, so that within a very few minutes it is quite black. The juice at this time contains about 12 percent sugar and has a density of from 13 to 15 degrees Brix.* It contains all substances dissolved by the diffusion process, the organic substance consisting principally of saccharine and albumin, and the inorganic constituents chiefly of potash, lime, soda, magnesia, phosphoric acid, and chlorine. This juice always shows an acid reaction.

The juice is then passed through pulp removers, consisting of screens, serving as strainers for removing any pulp or fiber which may have been separated by the juicers. It is then measured, the density recorded and it is pumped into a reheater where it is heated to about 90 degrees C., in order to coagulate certain substances, thus rendering them insoluble.

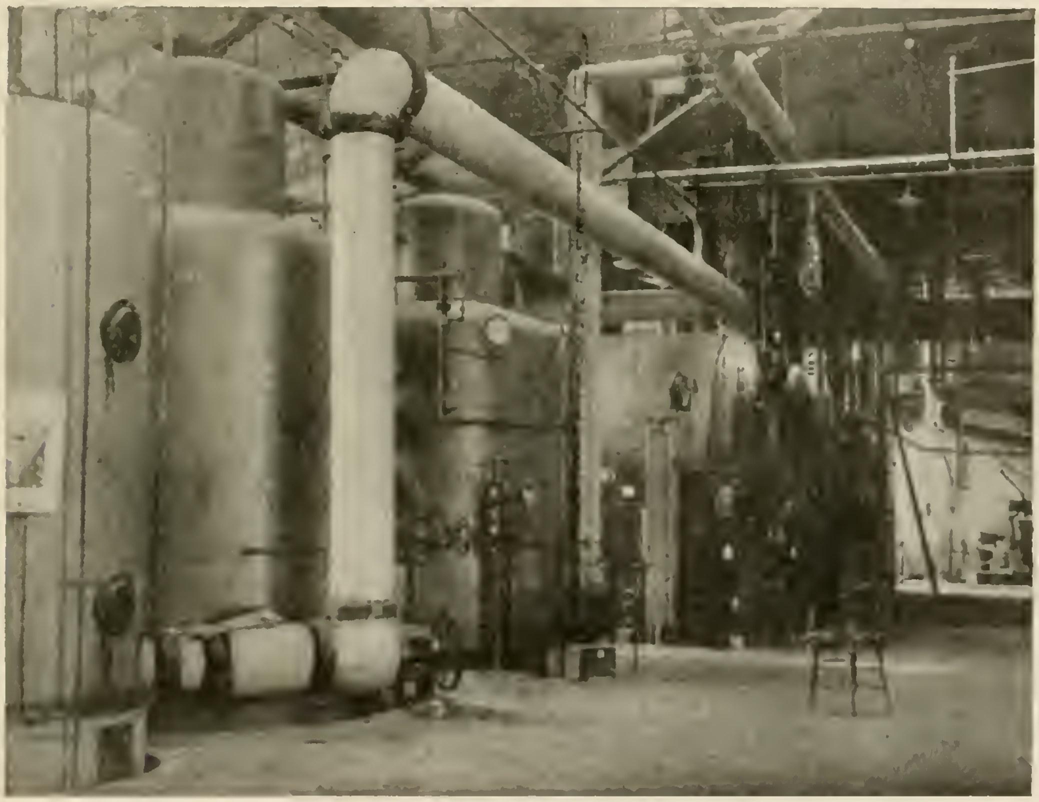


FIG. 5—A GENERAL VIEW OF THE EVAPORATORS FOR BOILING DOWN THE SYRUP OBTAINED FROM THE DIFFUSION BATTERIES

Defacation Tanks—From the reheaters the raw juice is next pumped into tanks where milk of lime is added for clarification and purifying. The tanks are equipped with a simple stirring device for mixing quickly. The action of the lime upon the raw juice is both chemical and mechanical; chemically it acts as a precipitant and decomposes the non-sugars; the mechanical purification is due to the fact that suspended matter is carried down with the precipitate. Defacation requires about fifteen minutes at a temperature of 70 to 80 degrees C. Lime is required to the amount of one and one-half to two percent of the weight of the juice.

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*One degree Brix is equal to 1.8 degrees Baume.

Carbonation Tanks—The mixture from the defacation tanks is emptied into carbonation tanks, where carbon dioxide is added, forming a precipitate of calcium carbonate which carries down with it much of the coloring matter and various impurities. The mixture is then passed through filter presses, the precipitate being dropped into a spiral conveyor, which conveys it to mixing tanks called mud scrolls, where it is mixed with water, in order to reduce it to a consistency so that it can be handled by a pump. The filtered juice is then passed through a second carbonation tank where carbon dioxide is again added for combining with any lime present, also for neutralizing the juice. The juice from the second carbonation tank is also filtered to remove the remaining impurities and precipitation.

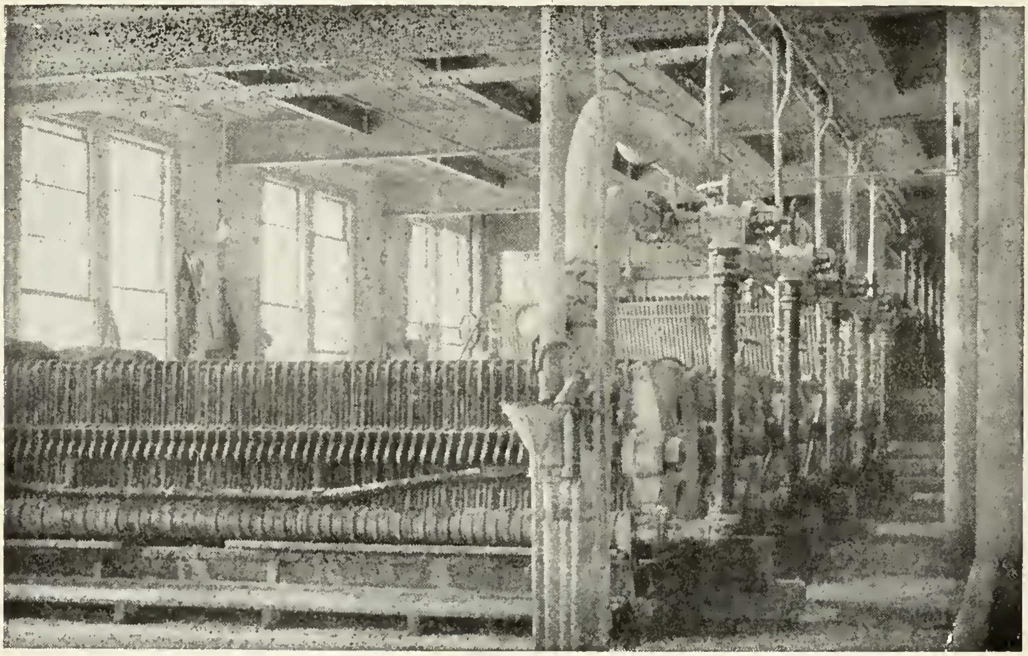

FIG. 6—FILTER PRESSES, FOR FILTERING THE LIQUID IN VARIOUS STAGES OF THE PROCESS

Evaporators—By means of evaporating apparatus, the thin juice is concentrated from a density of 12 to 13 degrees Brix, to a syrup of about 60 degrees Brix, evaporating about 80 percent of the water. From the evaporators the syrup enters a tank where it is mixed with brown sugar syrup obtained further along in the process. It is then heated, and pumped to the sulphur station where sulphuric dioxide is added for clarification, the precipitate being removed by filtering.

Vacuum Pans—The syrup is next run into white sugar vacuum pans where the syrup is boiled until microscopic grains are formed, more syrup being added from time to time until the grain is enlarged to the required size. The contents of the pan is then dumped into a hopper from which the mass is drawn off into the centrifugal machines. White sugar mixers or scrolls are used for keeping the mass agitated until drawn off by the centrifugal machines.

White Sugar Centrifugal Machines—About 600 pounds of the mass is drawn off from the hopper into the centrifugal machines, each of which consists of a bucket shaped receptacle, called a "basket" with perforated sides. The basket is suspended from the lower end of a shaft which is fastened to the bottom of the basket. The baskets are filled either while at rest or while revolving slowly, and then are brought quickly up to full speed. The heavy syrupy mass, consisting of approximately half sugar and half molasses, is forced up on the side of the basket, but kept from spilling out by a flange surrounding the top. The molasses

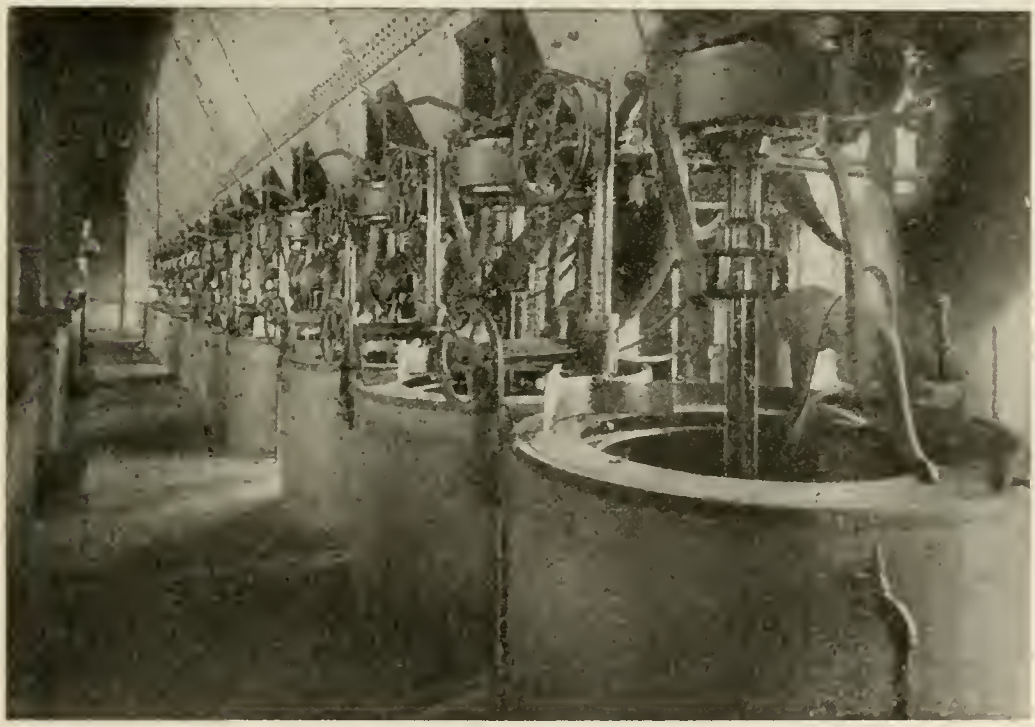

FIG. 7—FOURTEEN 40-INCH SUGAR CENTRIFUGALS DRIVEN BY THREE SQUIRREL-CAGE MOTORS

Two groups of four each are driven by 50 horse-power motors and one group of six, by a 75 horse-power motor. The centrifugals operate at 1 000 r.p.m. The syrup enters through the large curved pipe at the right of each machine, and drops into the suspended basket. After the molasses has been thrown off, the sugar is discharged through the bottom of the basket.

is forced out of the small holes in the side of the basket while the sugar is retained.

The mass as it enters is dark brown but as the molasses is forced out the sugar gradually whitens. After the sugar has spun for about 60 seconds it is washed with water while revolving, the centrifugal is brought to a stop, and the sugar is scraped from the sides of the basket with a paddle and emptied through an opening in the bottom into a conveyor which conveys the sugar to the granulators.

Crystallizers—The molasses or green syrup that is thrown off by the centrifugal machines contains a saccharine substance that has not crystallized in the process of evaporation and boiling. This syrup is emptied into tanks called "crystallizers" where it is slowly stirred for about sixty hours, the continued stirring action causing it to crystallize. It is then pumped to the brown sugar vacuum pans, boiled, and sent to the brown sugar centrifugal machines. The sugar thus obtained is brown but cannot be used as such, as the brown sugar obtained from beets is not palatable, owing to certain impurities contained therein. This sugar is conveyed to a sugar melter where it is melted to a syrup after which it is run off into the brown sugar mixer and mixed with

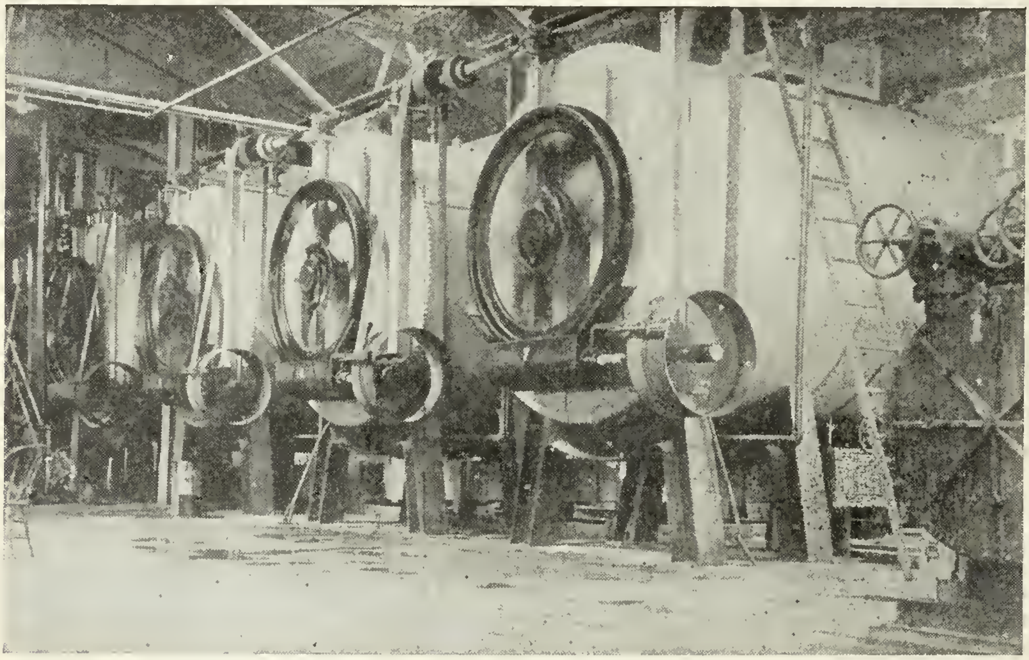

FIG. 8—A GROUP OF SEVEN CRYSTALLIZERS DRIVEN BY A 20 HORSE-POWER SQUIRREL-CAGE MOTOR

The crystallizers are ten feet in diameter by 16 feet long. The large worm gear-wheel at the end of each machine is on the agitator shaft and is making one revolution in four minutes.

the syrup coming from the evaporators, as previously mentioned.

Hot Tube Mill or Granulator—The wet white sugar from the white sugar centrifugal machines is passed through a revolving screen, in which a circulation of hot air, together with a revolving steam drum in the tube, dries the sugar as it gravitates from one end to the other. The hot granulated sugar is then passed through another revolving tube, and is cooled with a current of cool air obtained by means of a blower. The sugar in leaving the tube passes through a screen in the lower end, which retains the lumps.

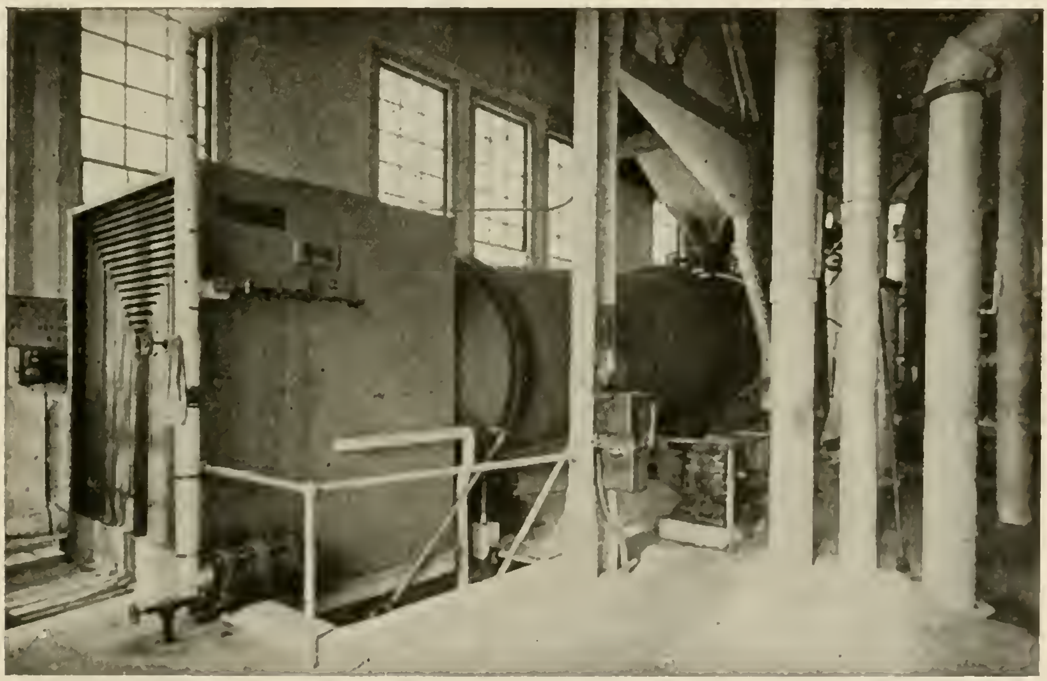

FIG. 9—A SIX BY 20 FT. GRANULATOR, ELEVEN R.P.M., DRIVEN BY A 15 HORSE-POWER SQUIRREL-CAGE MOTOR

The wet sugar enters at the far end of the tube and is dried by coming in contact with air heated in passing over the steam coils. A 24 inch exhaust fan, 452 r.p.m., is used for drawing the hot air through the tube.

Sugar Sackers—The dried and cooled sugar is dropped into sugar sackers which automatically permit only a fixed quantity of sugar to be drawn off into the sacks. After the bags are filled, they are placed on a conveyor which conveys them to a sewing machine where the top of the bag is closed while the sack of sugar is carried past the machine by the conveyor. The sacks are then conveyed to a storehouse where they are stacked. A portable conveyor, elevating the sacks at an angle, is used for stacking the sacks high above the floor.

Steffens Process—This process is frequently used for the recovery of the sugar from the molasses thrown off by the brown sugar centrifugal machines. The molasses is diluted with water and artificially chilled below 15 degrees C. Quick lime is then added in small portions, the total quantity being about equal to the weight of the sugar in the molasses. No reaction of the lime takes place so long as the liquor is kept cool. The lime at first goes into solution, but eventually separates as a tricalcium saccharate $(CaO)_3C_{12}H_{22}O_{11}$, containing the sugar and lime. The mixture is then passed through a filter press, where the tricalcium saccharate is filtered off. After washing the precipitate it is conveyed to cold and hot saccharate mixing tanks for removing the sugar from the lime. Cold water is first added which dissolves a large amount of the sugar. The mixture is then pumped into another tank where it is heated, the slacking of the lime assisting in raising the temperature. The remaining portion of sugar which was not recovered at the low temperature is given up at the high temperature. The mixture is then pumped into the defacation tanks, as above described, where the sugar in the mixture combines with the raw juice from the diffusion batteries, and the lime is used for the defacation process.

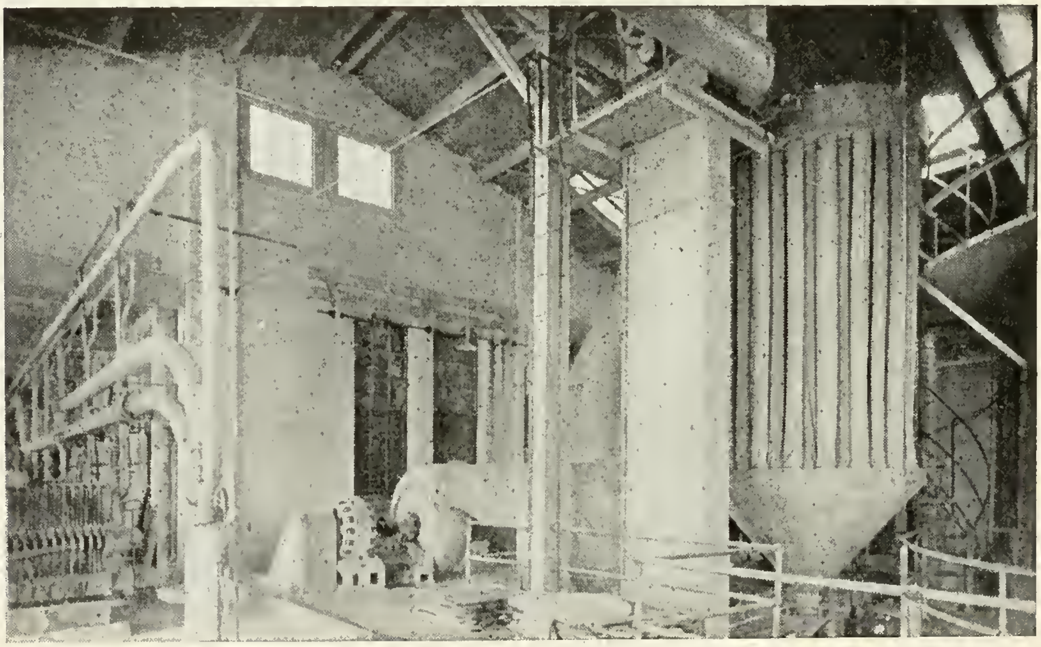

FIG. 10—A 75 HORSE-POWER, 1 135 R.P.M. SQUIRREL-CAGE MOTOR, DRIVING A SPECIAL EXHAUST FAN, ALSO A LIME PULVERIZER ON THE FLOOR BELOW

POWER REQUIREMENTS

Of ten steam engine driven beet sugar factories visited by the author the average output of the factories in terms of indicated horse-power was as follows:—

Indicated horse-power per ton of beets consumed per 24 hrs.—0.66.
Indicated horse-power per ton of sugar output per 24 hrs.—5.3.

These figures do not include the amount of power required by the Steffens process inasmuch as all factories do not employ this system of reduction. The following statement of the actual power required for a completely electrified factory, using both individual and group drive allows of an interesting comparison.

Horse-power input per ton of beets consumed per 24 hrs.—0.33.
Horse-power input per ton of sugar output per 24 hrs.—2.2.

The comparison indicates the losses in the line-shafts, belts and various forms of power transmission when using steam engines for driving machinery. With electric motors properly applied the power consumption should not be over one-half of that required for steam engine driven factories.

INDIVIDUAL POWER REQUIREMENTS OF SUGAR MACHINES

The following machines vary in size according to the individual requirements, but will serve as a guide as to the average practice.

Beet Lift—16 ft. dia. by 2 ft. wide, with 32 buckets, 12 in. deep, making four r.p.m., driven by pinion meshing with an eight-foot gear on lift. Ten horse-power required, constant speed, high starting torque.

Beet Washer—6 ft. dia. by 18 ft. long, with thirty-two 24-in. arms or paddles. Shaft makes 14 r.p.m. Seven and one-half horse-power required, constant speed, moderate starting torque.

Beet Elevator—34 buckets, 22 in. wide by 17 in. deep. V-shaped, 70—120 ft. per min. Ten to 20 horse-power required, constant speed, moderate starting torque.

Beet Slicer—Capacity 50 tons per hour, 55 r.p.m. Twenty-five horse-power required, constant speed, high starting torque.

Cossette Conveyor—Capacity 60 tons per hour, belt 12 in. wide by 125 ft. long, belt speed, 250 ft. per min. Five horse-power required, constant speed, light starting torque.

Sugar Mixers—Shaft 50 ft. long, 12 in. paddles, speed 1.5 r.p.m. Ten horse-power required, constant speed, moderate starting torque.

Tube Mill or Granulator—6 ft. dia. by 30 ft. long. 10 r.p.m. Ten horse-power required, constant speed, high starting torque.

Crystallizers—10 ft. dia. by 16 ft. long, paddles, 4.5 ft. long secured to driving shaft making one revolution in five minutes. The power required varies considerable during the cycle of operation, the amount of power required at the completion of the operation being almost double that at the start. For this reason the machines are best driven in groups of from four to eight, by one motor. For driving an individual machine from 2.5 to 3 horse-power is required at the beginning of the cycle, and five horse-power at the end. Since the complete operation may require 60 hours, a motor must have sufficient capacity to operate at maximum capacity continuously if individually driven. Where crystallizers are driven in groups of from four to eight machines, three horse-power per crystallizer is sufficient.

The Sugar Centrifugal is one of the most important machines in sugar making, the operating conditions being very severe, due to the inertia of the load and the cycle of operations. The time required for the complete spinning process varies with the grade of sugar. Ordinarily one man can operate two centrifugals on the granulated sugar, and up to four centrifugals on white sugar. When these machines are to be individually driven, the cycle of operation must be known, as the rating of the motors will depend upon the *root mean square* value of the power requirements, and the torque required for accelerating in a given time. The average cycle of operation for different grades of sugar is as follows:—

FINE GRANULATED SUGAR—GROUP DRIVE.

Filling—¼ speed	30	seconds
Accelerating, ¼ to full speed	10	“
Full speed	120	“
Power off, retarding by braking	20	“
Revolving at about 25 r.p.m.	30	“
Total time 3 minutes,	30	seconds

FINE GRANULATED SUGAR—INDIVIDUAL DRIVE.

Filling basket, revolving by hand	10	seconds
Accelerating	100	“
Full speed	30	“
Power off, retarding by braking	20	“
Stop, unloading by hand	60	“
Total time 3 minutes,	40	seconds

COARSE GRANULATED SUGAR—INDIVIDUAL DRIVE.

Filling basket, revolving by hand	10	seconds
Accelerating	60	“
Power off, retarding by braking	20	“
Stop, unloading by hand	60	“
Total time 2 minutes,	30	seconds

SOFT WHITE SUGAR—INDIVIDUAL DRIVE.

Filling basket	25	seconds
Accelerating	100	“
Full speed	15	minutes
Power off, braking	30	seconds
Stop, unloading by hand	145	“
Total time	20	minutes

Centrifugal machines furnish an especially good proposition for group drive, although individual drive has been successfully used to a much lesser extent. The character of the load is very similar to that of a fly-wheel, so that with these machines arranged in a group and driven by one motor, the centrifugals in operation will help to bring the idle machines up to speed and maintain a uniform load on the motor. This can best be shown by the following data, taken on a group of ten 40-inch centrifugal machines, driven by a 100 horse-power motor.

1 machine starting	20.5 horse-power
2 machines starting, 1 at full speed	40.0 horse-power
3 machines starting, 3 at full speed	52.5 horse-power
4 machines starting, 4 at full speed	60.0 horse-power
1 machine at full speed	5.5 horse-power

Owing to the inertia of the line shaft and pulleys the peak loads which come on the line are considerably less with the group-driven centrifugals than with those direct-connected. With group drive, the motor is required to start up a line shaft having a large number of pulleys and hangers so that the inertia to be overcome at starting is quite large, requiring a motor of good starting characteristics. With individual drive the peak load is about eight times the normal running load; for a 40-inch machine the peak is approximately 40 kw input, corresponding to about 40 hp output, but since at the very start the speed is zero, the horse-power is zero, therefore, the power required at start should be stated in terms of pounds torque at one foot radius. The starting torque, together with the root mean square horse-power for the cycle, furnishes sufficient data for determining the motor required.

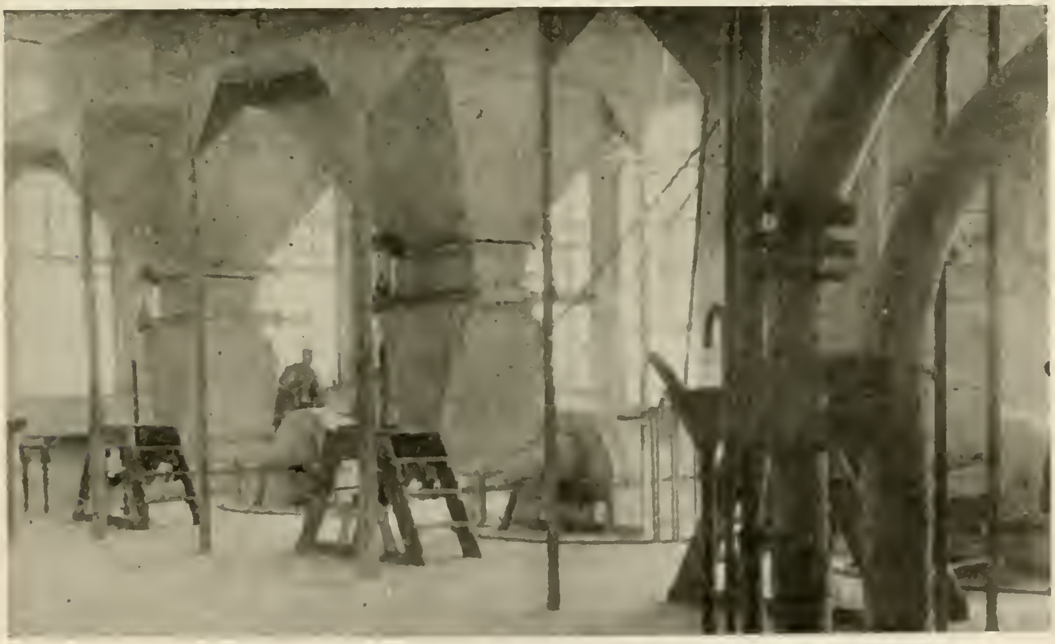

FIG. 11—THREE LIME SIFTERS AND FIVE STIRRING TANKS OPERATED BY A 40 HORSE-POWER SQUIRREL-CAGE MOTOR

This is part of the Steffens process equipment.

The speed of a direct-connected centrifugal machine increases very rapidly at the start and at a much lesser rate as the motor approaches synchronous speed. The motors are usually of the squirrel cage type with high resistance end rings designed to give approximately 15 percent slip at full load, but since full load is never attained, except at starting, the maximum speed attained by the centrifugal is almost synchronous speed. In nearly every case the operation is completed before the machine has attained its highest possible speed.

The torque necessary for starting a loaded centrifugal machine, and accelerating it to a given speed in a certain length of time is determined by the following formulae:—

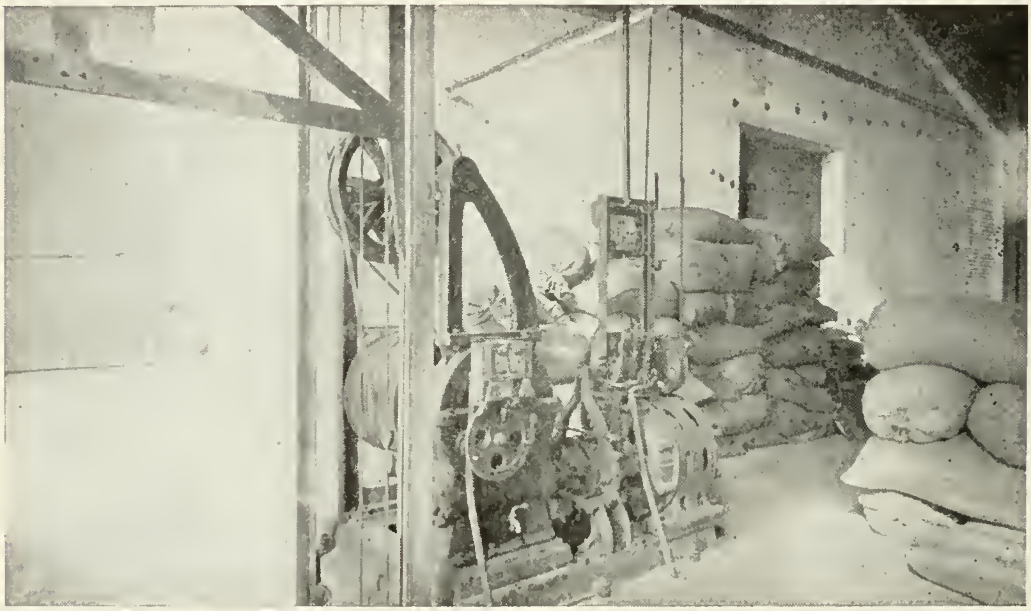

FIG. 12—A 4 000- POUND FREIGHT ELEVATOR OPERATED BY AN ELEVEN HORSE-POWER SQUIRREL-CAGE INDUCTION MOTOR

Let T = Pounds torque at one ft. radius.
Let W = Weight in pounds to be accelerated.
Led R = Radius of gyration, in feet, of entire mass.
Let N = R. P. M. machine will attain in S seconds.
Let S = Seconds required for accelerating.

$$\text{Then } T = \frac{W R^2}{32.2} \times \frac{2 \pi N}{60 S}$$

The above amount does not take into consideration friction and windage and it will be necessary to increase the output thus obtained by ten percent in order to obtain the required starting torque.

HOLLY SUGAR COMPANY

A notable example of a completely electrified sugar factory is the Holly Sugar Company's factory at Huntington Beach, California. Work on this plant was begun January 1st, 1911, and the factory was finished completely and placed in operation July 28th, 1911. This plant was designed for a capacity of 600 tons of beets or 180 000 pounds of sugar per twenty-four hours. The daily output for the first campaign averaged 732 tons of beets or 201 800 pounds of sugar. The output has increased each year, the greatest being during the campaign of 1912, which averaged 1130 tons of beets consumed and 339 000 pounds of sugar output for twenty-four hours.

The illustrations which accompany this article were all taken at the plant of the Holly Sugar Company, and in Tables I, II and III is presented data with regard to the motor and generator requirements and also the power consumption at this plant. The curves shown in Figs. 1, 2, 3 and 4 show the power consumption per ton of beets sliced; per ton of sugar output; and the maximum, minimum, and average kilowatt demand and power-factor.

TABLE I—MOTOR DATA

Hp of motors, beet machines	75
Hp of motors, sugar machines	281
Hp of motors, pumps	207.5
Hp of motors, Steffens plant	250.0
Total hp of motors installed	813.5
Input to motors, beet machine	58.3
Input to motors, sugar machines	268.3
Input to motors, pumps	184.3
Input to motors, Steffens plant (approx)	250.0
Total hp input to motors	761.1
Total rated hp capacity of motors required for beet machines	64.0
Total rated hp capacity of motors required for sugar machines	283.5
Total rated hp capacity of motors required for pumps	193.0
Total rated hp capacity of motors required for Steffen plant	250.0
Total rated hp capacity of motors required for entire plant	790.5
Total hp output of motors assuming 86 percent efficiency	670.0

TABLE II—HORSEPOWER INSTALLED PER TON OF BEET SLICED PER 24 HRS.

Beet machines	.075
Sugar machines	.231
Pumps	.207
Steffens plant	.250
Entire factory	.314
Beet and sugar machines	.356

TABLE III—HORSEPOWER INSTALLED PER TON OF SUGAR PER 24 HRS.

Beet machines	0.469
Sugar machines	1.81
Pumps	1.36
Steffens plant	1.565
Entire factory	5.08
Beet and sugar machines	2.279

THE TUNGSTEN LAMP AND ITS DEVELOPMENT*

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NO less a man than Justus von Liebieg predicted in one of his "Chemical Letters" published in 1844, the appearance of an incandescent lamp burning without air and flame. In the following year Grove† published a description of an electric incandescent lamp consisting of a platinum wire which was brought to incandescence in rarefied air, the latter being sealed off by water, as shown in Fig. 1. The current supply to the platinum spiral was produced by Grove cells. This lamp was not practical on account of its great inefficiency, the surrounding media, viz., air and water, absorbing heat at the expense of energy somewhat as in the Nernst lamp. At about the same time Moleyns described a platinum lamp consisting of a spiral *L,* Fig. 2, of platinum wire, rendered incandescent by the electric current led in at *a* and *b*. In order to increase the effect of incandescence Moleyns provided, above the platinum spiral, a tube with finely powdered carbon, which latter, falling on the platinum spiral, was burned in the air, thereby producing a brighter light. Lamps of this description could not be of any value for illuminating purposes as, on the one hand, in consequence of the burnt carbon, a heavy deposit quickly accumulated on the glass wall *M,* which ren-

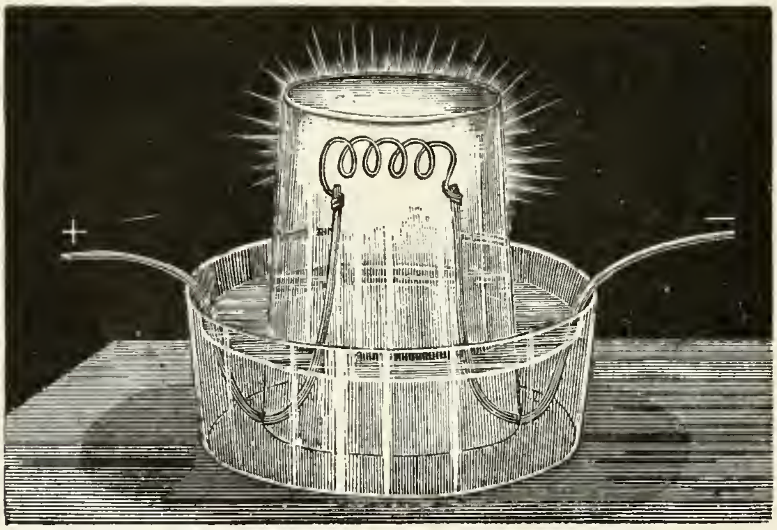

FIG. 1—EARLY PLATINUM WIRE INCANDESCENT LAMP

dered them uneconomical, and on the other hand the platinum wire deteriorated due to corrosion by the carbon.

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*Translated from a paper read at the Ninth Annual Meeting of the Vereinigung Österreichischer-Ungarischer Elektrizitätswerke in Salzburg.

†In the "Philosophical Magazine" of 1845, Vol. XXVII, page 442.

In the years 1877-78 Sawyer & Mann and Edison brought out their new incandescent lamp in which a glowing body consisting either of carbon or platinum was made incandescent by means of the electric current in an evacuated glass vessel. Sawyer & Mann must be considered the real founders of the carbon incandescent lamp industry. They were the inventors of the so-called "Flashing" of filaments, although the invention was accidental, that is to say, as they had no means of producing a vacuum in a simple way, they took refuge in illuminating gas, in order to prevent the filament from being consumed by the oxygen of the air. They noticed a deposit on the filaments of such lamps which led them to the idea of illuminating gas to equalize uneven spots which often occurred in the filament, and as a matter of fact this method of treatment by depositing an equalizing carbon layer has been made use of up to the present day. Edison, who originally started with metals, in the course of time left this field and, in the same way as Sawyer & Mann, proposed the use of carbon as an incandescent body. Besides the above named, should be mentioned first of all Swan who, in 1879, carried out further improvements in the carbon lamp. In addition, mention must also be made of Star and King, also Goebel and Lodyguine, all of whom have shared in the development and improvement of the carbon lamp.

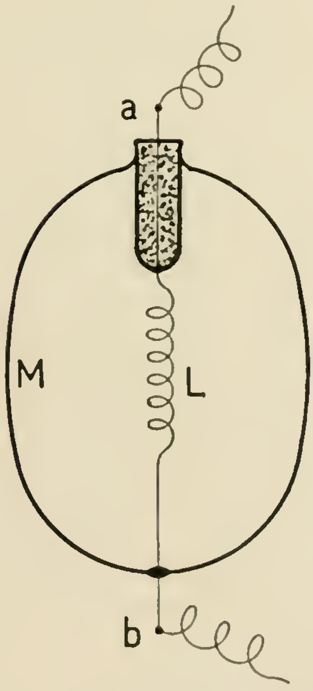

FIG. 2—PLATINUM CARBON LAMP

Nevertheless the practical use of the carbon lamp is due to Edison. Although the Kirchoff theory as regards the distribution of the current was already established (1838, 1845, 1847), Edison was the first to make use of the division of current in a practical way. He was the first to start electric lighting on a large scale. In 1879 the Mississippi steamer "Columbia" had been fitted throughout with electric light. Thus Edison has the merit of having introduced lighting by means of electric incandescent lamps.

It should not be forgotten that arc lamps were known previous to that time and had also been in more or less practical use.

Since the early 80's the carbon incandescent lamp has quickly come into more and more extended use, and until about the close of the 90's it remained supreme in the electric lighting industry. In 1897 Nernst brought out his electric incandescent lamp containing conductors of the second class as the light emitting bodies. This lamp, however, never succeeded in becoming universally popular, most probably on account of difficulties connected with its use. With such lamps advantage can never be taken of all the available energy, a considerable portion being diverted to the atmosphere in the form of heat. It is impossible to glow the Nernst incandescent body in vacuo on account of the fact that it is thereby disassociated. Besides an important competitor to the Nernst lamp soon appeared; Auer von Welsbach discovered that in the platinum group of metals, especially osmium, were particularly suitable bodies for electric lighting, and one or two years later he introduced the osmium lamp on the market.

In 1903 the tantalum lamp, an invention of Werner von Bolton, arrived, and finally, in 1905, the tungsten lamp made its appearance on the market and still maintains the preëminent position it obtained at the outset. Of course, it should not be forgotten in this connection that a change has taken place in the manufacture of tungsten lamps, drawn wire now being substituted for squirted filaments. As regards the metal tantalum, it was the natural method from the first to produce drawn wires in view of the fact that this metal lends itself without difficulty to rolling and drawing.

The value of any material for the purposes of giving light depends upon its radiating properties. The spectrum obtained by splitting up sun light or an ordinary source of light by the aid of a prism or a deflecting screen, as in Fig. 3, is only a small part of the whole spectrum, which contains, besides the

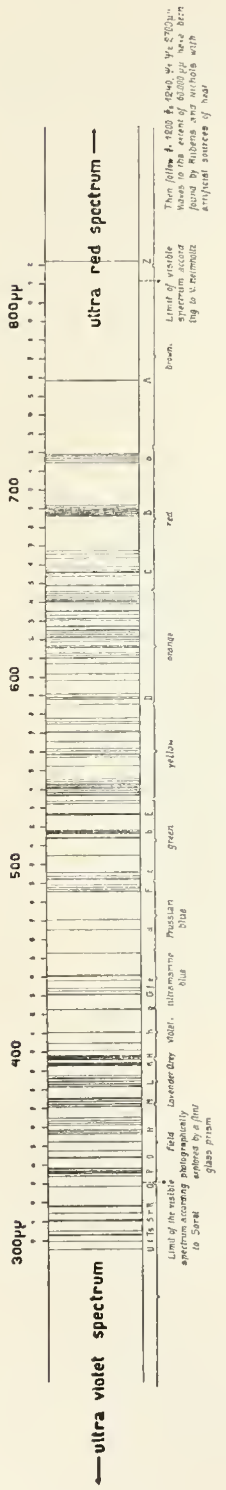
ultra red spectrum
ultra violet spectrum
800μμ
700
600
500
400
300μμ
Then follow waves to the extent of 60,000 μμ found by Rubens and Nichols with artificial sources of heat
Limit of visible spectrum according to v. Helmholtz
brown
red
orange
yellow
green
Prussian blue
ultramarine blue
violet
Lavender Grey
Limit of the visible spectrum according to Soret
Field explored photographically by a flint glass prism
Z
A
B
C
D
E
b
F
G
H

FIG. 3—NORMAL SUN'S SPECTRUM

part consisting of visible rays of varying wave length (from 0.4 to 0.8*m*) composing the seven colors, further regions invisible to the eyes. The limits of the invisible spectrum extend beyond both sides of the visible one. From red downwards rays of increasing wave lengths are found up to 341 *m* (Rubens) the heat rays or so-called ultra red rays. Beyond the violet region of the spectrum the wave length of the rays decreases. The invisible part of the spectrum consisting of short waves is called the ultra-violet spectrum. The ultra-violet rays are characterized by their chemical activity. By their means photo-chemical effects are obtained and they are of importance for the vegetable world as the assimilation of plants is due to their influence.

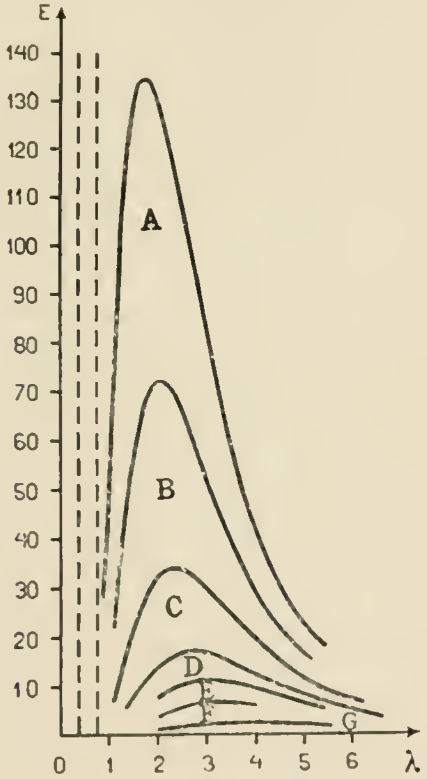

FIG. 4—ENERGY CURVE OF A BLACK BODY

A = 1 845 degrees C.
B = 1 680 degrees C.
C = 1 480 degrees C.
D = 1 388 degrees C.
E = 1 278 degrees C.
F = 1 152 degrees C.
G = 802 degrees C.

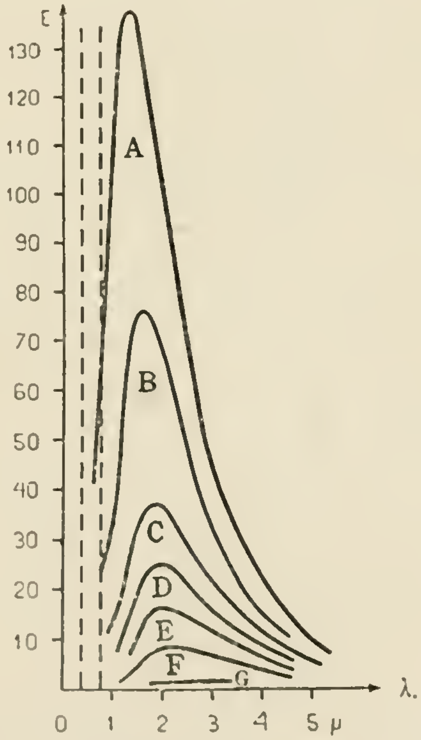

FIG. 5—ENERGY CURVE OF POLISHED PLATINUM

A = 1 646 degrees C.
B = 1 460 degrees C.
C = 1 259 degrees C.
D = 1 005 degrees C.
E = 998 degrees C.
F = 904 degrees C.
G = 723 degrees C.

For lighting purposes, as will easily be understood, only the visible part of the spectrum is of importance. Unfortunately among the known heat radiating bodies—and these alone will be considered here—there is none that radiates visible rays exclusively, when heated, that is to say, having a wave from 0.4 to 0.8 *m*. As a rule the number of invisible compared with visible rays radiated is very unfavorable for lighting purposes, as the former exceed by far the visible ones. However, not all bodies show the same proportions in this respect. The black body, although its radiation for every wave length is superior to any other body, is still the most uneconomical one because it radiates a maximum of energy also in the invisible regions, so that the proportion of the number of invisible rays to the number of visible rays also represents a maximum. Fig. 4 is the energy curve of the black body, Fig. 5 is that of platinum. The abscissae in both cases represent the wave lengths in microns, whereas the ordinates represent the emissivity. The two limits of the visible spectrum are shown by the broken lines at 0.4 and 0.8 *m*. Both the curves show that the proportion of the number of invisible ones at equal temperature is greater with the black body than with platinum, consequently platinum radiates more selectively than the black body. Lummer's remark, that the process of obtaining light by heating the black body is similar to the foolish attempt of striking all the keys of a piano in order to sound the highest octaves, is much to the point. Therefore the endeavor to use bodies having only partial radiation, i. e., so-called selective radiators, as source of light is the only correct one.

The Lummer-Pringsheim doctrines with regard to the distribution of energy in the spectrum of metals imply that the maximum energy progresses in proportion to the sixth power of the absolute temperature and that the product of the absolute temperature and the wave length of maximum energy is constant. It is therefore clear that bodies which are capable of resisting the highest temperatures, that is to say, bodies having the highest melting points, must form the most advantageous sources of light because, first, a high total amount of energy is obtained from them and, second, their maximum of energy is found with short wave lengths, that is to say, to a greater extent within the visible region. Obviously this fact is followed by the question, which of known substances has the highest melting point.

At the time Auer von Welsbach invented the Osmium lamp the Lummer-Pringsheim doctrines were not known, nor were exact determinations of melting points available, these being only lately ascertained, as formerly the necessary methods and apparatus were not in existence. There remained no other key than the known statements of L. Meyers and Mendelejeff on the periodic system of elements which, it must be added, are based to a greater extent upon combinations than upon the results of practical experiments. Fig. 6 shows their curve representing the sequence of related elements according to their atomic weight and volume.

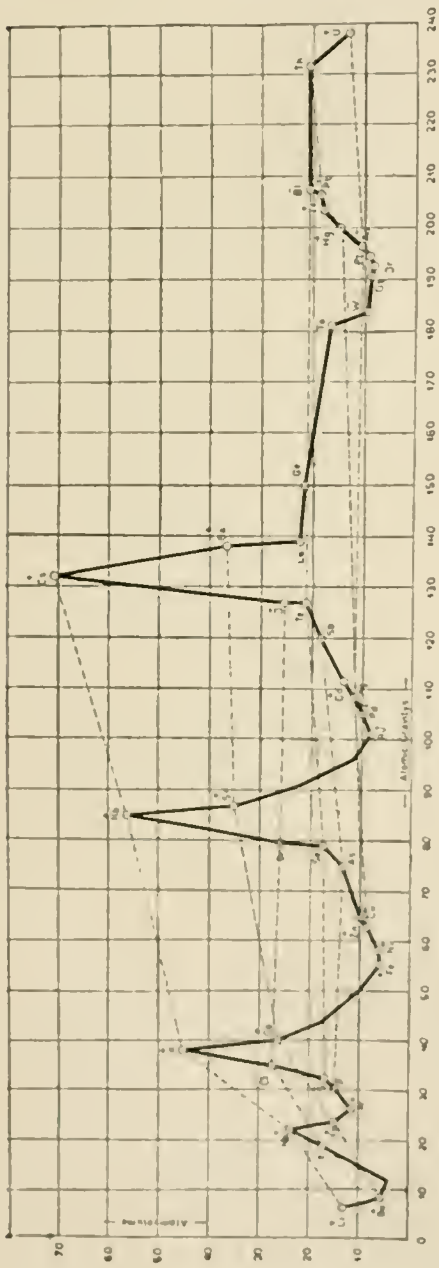

FIG. 6—ATOMIC VOLUME OF ELEMENTS ACCORDING TO THEIR DEPENDENCY ON THE ATOMIC WEIGHT

In a purely empirical manner Auer von Welsbach chose osmium, which seemed to have the highest melting point of the known metals. Incited by his success, experiments were extended to other metals with an equal result. Thus tantalum and tungsten came to be used as glowing bodies for incandescent lamps. The typical way of manufacturing a filament from metals, osmium for example, which at the time were termed brittle metals, was invented by Auer. His method consists in mixing osmium in a finely divided state with an organic binding agent to form a paste from which filaments were squirted. The squirted filaments are subjected to a heating process in vacuo in the course of which the carbon separates from the organic combination in which it is contained in the binder, so that the filament then consists of osmium and carbon. Then the osmium-carbon filament is subjected to the action of an electric current or to a high temperature in an atmosphere consisting of reducing gases in excess and oxidizing gases, for instance, steam, (the so-called forming treatment) during which the carbon is oxidized, the oxidation of the metal being prevented by the presence of the reducing gases. At the time when Auer made his experiments, the commercial manufacture of hydrogen was hardly known, so that he was forced to obtain the required reducing gas in another way. For this purpose he invented an experimental arrangement which may be termed classical, in which he made use of the gas from a Bunsen burner, which had lit back.

Fig. 7 shows the experimental arrangement. In the first place the exceedingly simple forming apparatus is shown, consisting of an India rubber stopper with the leading in wires and a glass bell covering the same. The glass bell is filled with reducing gas by being held for a few seconds over the lit back flame of a Bunsen burner. In the atmosphere thus obtained the filament is maintained in the incandescent state until it has acquired constant electric properties.

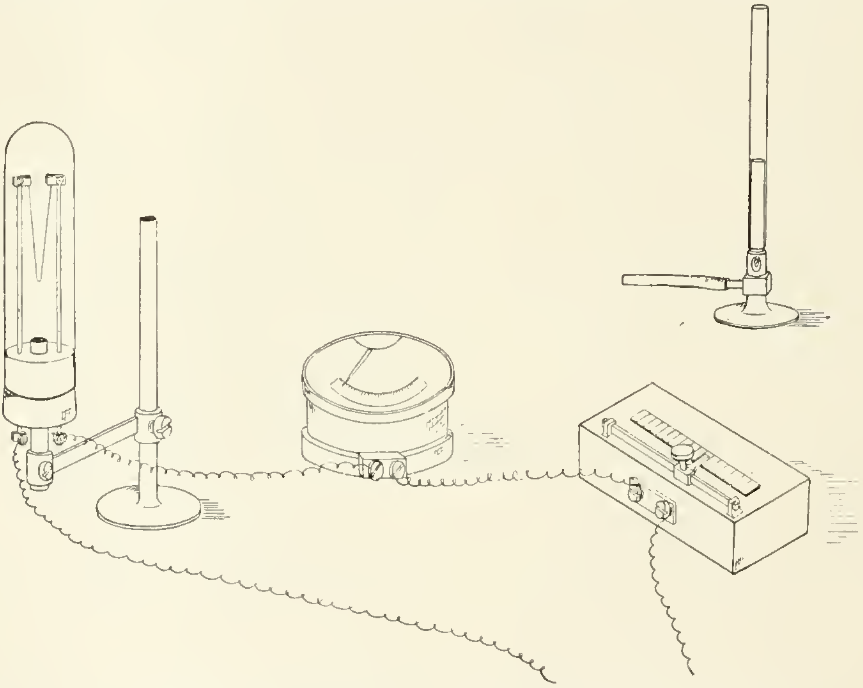

FIG. 7—EXPERIMENTAL APPARATUS FOR PRODUCING REDUCING GAS

With tantalum the procedure was somewhat different. This metal could be rendered ductile by previous melting and then transformed into wire by rolling and drawing.

With regard to tungsten, the procedure proposed by Auer could be followed without difficulty although the quantity of oxidizing gas had to be considerably reduced, tungsten being much more readily oxidized than osmium. The glowing process was carried on in hydrogen to which small quantities of oxidizing gases, for instance steam, were added to eliminate the carbon. Besides this paste process, which was of great importance in the manufacture of the tungsten lamp, there are a number of other processes in existence by which a pure tungsten lighting body can be obtained. In this connection the colloidal process must be specially mentioned, according to which a plastic mass is obtained from colloidal (finely divided) tungsten in aqueous solution. The characteristics of colloid are as follows:—By the term "colloids" are understood substances of gelatinous consistency. They differ from the so-called crystalloids by their small diffusing capacity. It follows that colloids, contrary to crystalloids, which form real solutions, as for instance, sugar and water, only apparently form solutions, whereas in reality, fine particles of the substance are suspended in the liquid, which, by dint of mechanical means, for instance filtration, may be separated. A correct idea may be formed of the colloids if the degree of division is compared to the fine dust particles as seen floating in the air whenever a ray of sunshine meets them across an aperture. An example of a colloidal solution is ink, in which iron-tannin is contained in a suspended state and forms a dense residue if the ink dries.

A further method of manufacturing tungsten filaments consists in the substitution process which, however, was never employed with success. It was replaced by the so-called coating process. The characteristic feature of the latter is that tungsten is deposited on a carbon filament, the carbon being subsequently eliminated by a chemical process whilst it is simultaneously brought to a glowing condition. A hollow metal filament results which, however, has the drawback of great unevenness. This is explained by the fact that the filament, while being treated, is sintered more effectively in some places than others, the metal walls frit together and the filament shows great differences as far as its resistance is concerned. This is the reason why this method was discontinued after a time and before it had been thoroughly practised.

Further mention must be made of a certain process using oxide of tungsten as raw material, the binding agent used being eliminated during the first glowing process and the oxide of tungsten simultaneously reduced.

A later method for manufacturing glowing bodies of tungsten consists in converting the metal which was formerly considered brittle into the ductile state, producing wires therefrom. As far back as 1893 Moissan described tungsten as being capable of mechanical working but only within recent times have tools been discovered to draw out tungsten into thin wires suitable for use as incandescent bodies. Various methods for obtaining this final product have become known. However, up to the present little has transpired in this connection, so that only one method will be here mentioned.* This method consists in forming, by pressure, bars from suitable tungsten metal powder, sintering them at a suitable temperature, whereupon they may be hammered, rolled and drawn whilst in a more or less heated condition. There is, however, nothing new in this method of mechanically producing incandescent bodies for electric lamps from brittle, intractable and highly infusible metals. For example, Staite, in the year 1848,** produced and exhibited electric incandescent lamps in which the glowing body was formed of a spiral of iridium. He made his spirals from powdered iridium or compounds of this metal which he sintered or melted together and from this ingot he manufactured bodies of the requisite dimensions by repeated mechanical treatment while the metal was in a highly heated condition. The mechanical treatment consisted of hammering and rolling, the metal being heated between and during each of these operations, which were continued until the metal was rendered sufficiently ductile.

TABLE I

	Tungsten 20 mm. diam.	Steel 20 mm. diam.	Tungsten 0.1 mm. diam.
Tensile strength	240 kg/mm²	80-130 kg/mm²	265 kg/mm²
Coef. of elasticity	37 600 kg/mm²	22 800 kg/mm²	38 800 kg/mm²
Torsional coefficient	9 000 kg/mm²	8 500 kg/mm²	10 400 kg/mm²

Drawn tungsten wire has the advantage of greater durability as compared with a squirted filament. This advantage is apparent, not only in connection with the transport and use of the lamp, but also during the process of manufacture. Tungsten wire, as far as its strength is concerned, is not only superior to the squirted tungsten filament but also to other materials such as steel, which may be seen from Table I. In this connection the strength of every material increases with a diminishing diameter. For instance, the values for tungsten wire of 0.1 mm diameter are as shown in the third column of Table I. With a diameter of 0.07 mm. the tensile strength even increases to 480 kg/mm^2. In

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*Brit. Patent No. 23,499—Thomson-Houston Company, dated 1909.
**Brit. Patent No. 12,212—1848.

order to determine the tensile strength of steel as well as tungsten a testing apparatus may be employed, based on the principle of a spring balance.

With pure tungsten incandescent bodies, a disadvantageous crystallization phenomenon has been observed to take place, more especially if alternating current is employed. It is a well-known fact that it is not necessary in order to crystalize a body that it should be melted or completely dissolved but mechanical and thermal influences suffice to bring about this modification. In the case of tungsten incandescent filaments, which are exposed to very high temperatures, crystallization takes place in a comparatively short time. When used with direct current the thickenings and wrinkles appear only in a longitudinal direction. When burn-

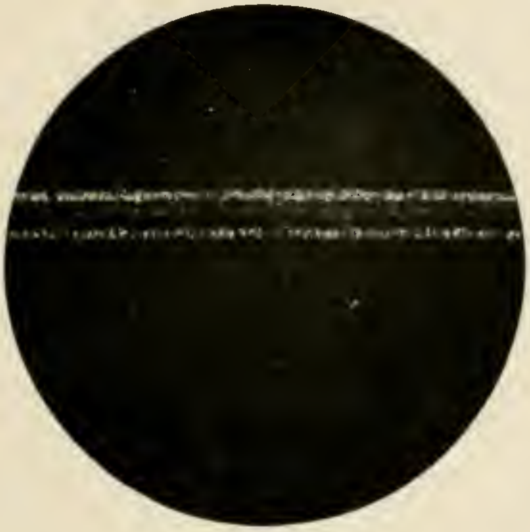

FIG. 8

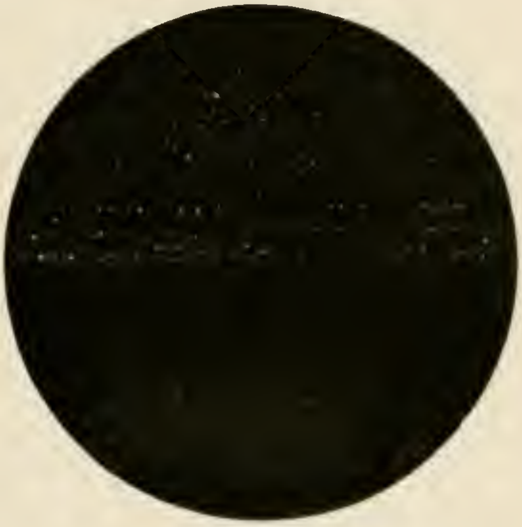

FIG. 9

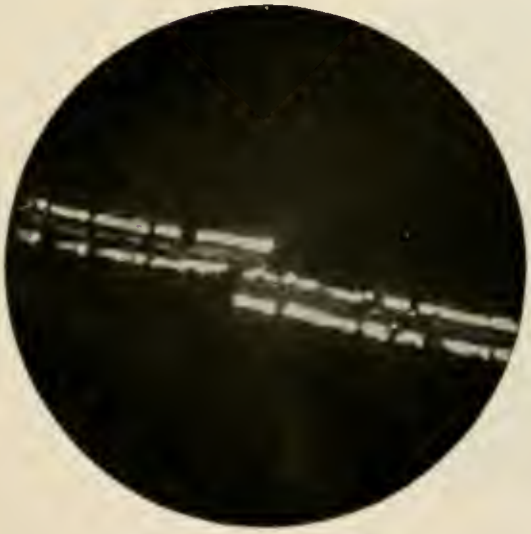

FIG. 10

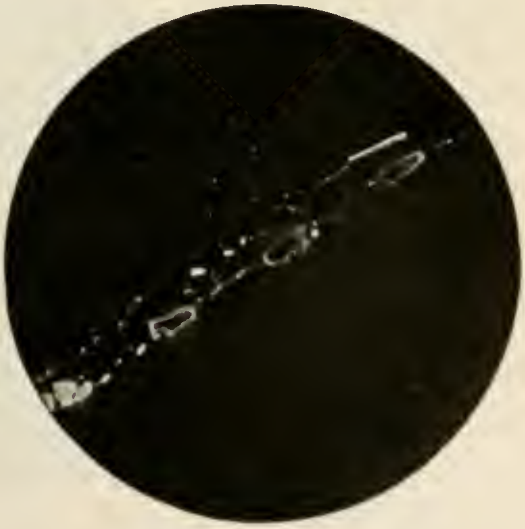

FIG. 11

ed on alternating-current circuits, the adjacent surfaces, owing to the dynamic influence of the surrounding magnetic field, are subjected to a sliding movement which, if it takes place in a direction perpendicular to the axis of the filament, causes considerable displacements of some parts of the filament, which eventually lead to their being separated, as shown in Fig. 10.

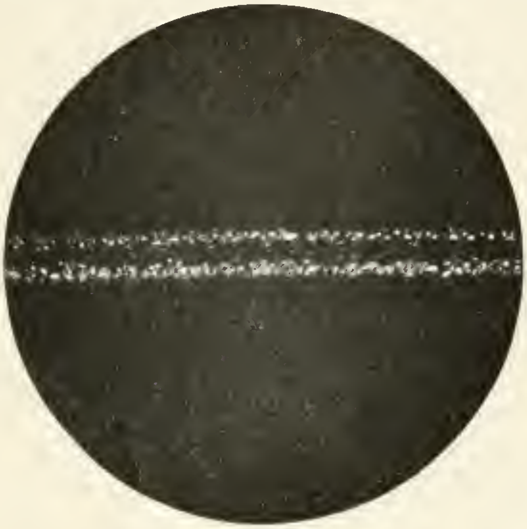

FIG. 12

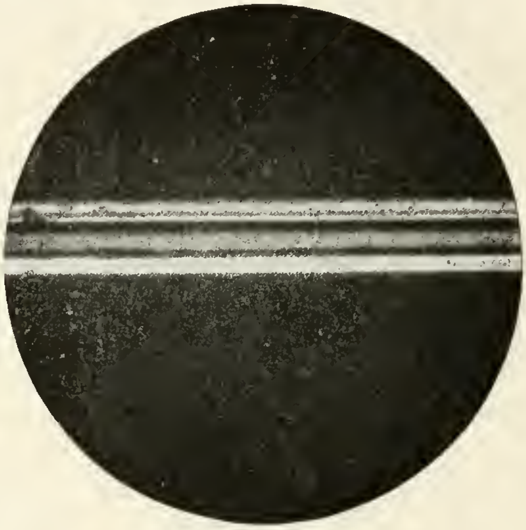

FIG. 13

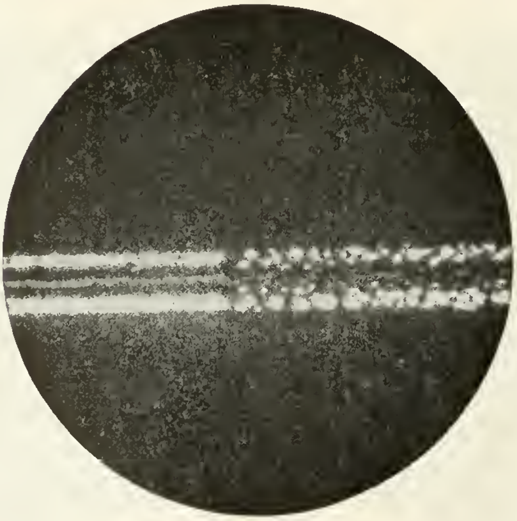

FIG. 14

It has been found that this drawback may be avoided by certain additions of compounds of the rare earth metals.* With such additions the tungsten incandescent body may be used equally well with alternating and direct current, be it a filament or wire. In this connection an essential improvement of the squirted filaments with such additions as regards their mechanical structure may be mentioned. Such filaments, contrary to the ordinary squirted filaments are quite ductile in the cold state. The disintegration due to crystallization also takes place with tantalum filaments. In order to illustrate the differences in the conduct of various types of filaments some microphotographs of tungsten filaments are given. Fig. 8 represents an ordinary squirted tungsten filament previous to being burnt, Fig. 9 shows the same after 600 and Fig. 10 after 1 000 hours burning, the two latter figures showing the characteristic structure for the alternating current. For comparison's sake Fig. 11 shows a filament after 1 000 hours burning with a direct current. Fig. 12 shows a filament with an addition of rare earth metal after 1 000 hours burning without any detrimental displacement. in spite of alternating current having been used. (No filament previous to being burnt has been represented here inasmuch as its appearance does not differ from that of the ordinary filament). Finally, Figs. 13 and 14 show tungsten wires previous to and after being used with alternating current. The characteristics of the materials which up to now have been taken into consideration in connection with incandescent lamps are given in Tables II and III. It must be observed that osmium. which, as is known, belongs to the metals of the platinum group, is an exceedingly expensive material, this being explained

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*Austrian Patent No. 41,247, Westinghouse Metallfaden Glühlampenfabrik, dated 1906.

TABLE II

Material	Atomic Gravity	Atomic Volume	Specific Gravity	Spec. Heat	Spec. Res.	Temp. Coef. $\alpha \times 10^3$
Carbon	12	3.6	3	0.1318	25	− 0.3
Osmium..............	190.9	8.5	22.48	0.03113	0.095	+ 3.7
Tantalum	181.5	14.3	16.8	0.0365	0.165	+ 2.9
Tungsten	184	15.5	19.1	0.0336	0.055	+ 4.3

TABLE III

Material	Watts per Hefner Candle	Ratio of hot to cold Res.	Temp. Coef. $\alpha \times 10^3$	Hefner candles per sq. mm	Temp. of incandescence	Melting point
Carbon	3.5	0.5	− 0.3	0.154	1800	Infusible
Osmium	1.5	8.94	+ 3.7	0.331	1900	2500 (Pictet)
Tantalum	1.6	6.07	+ 2.9	0.307	1700	2250-2300 (Bolton)
Tungsten	1.15	12.12	+ 4.3	0.441	2150	2740 (Pirani) 2794-2653 (Wartenberg)

by the fact that it is only found in platinum mines (Ural) in extremely small quantities. It was discovered by Tennant in 1803.

Tantalum was discovered by Eckenburg in 1802 and chiefly appears as tantalite. This metal likewise belongs to the rare elements, but is by no means as scarce as osmium. Tungsten, which was discovered by Scheele in 1781 belongs to the elements which are comparatively common. It is, however, nowhere found in the pure state. It chiefly occures as Scheelite (a calcium compound),

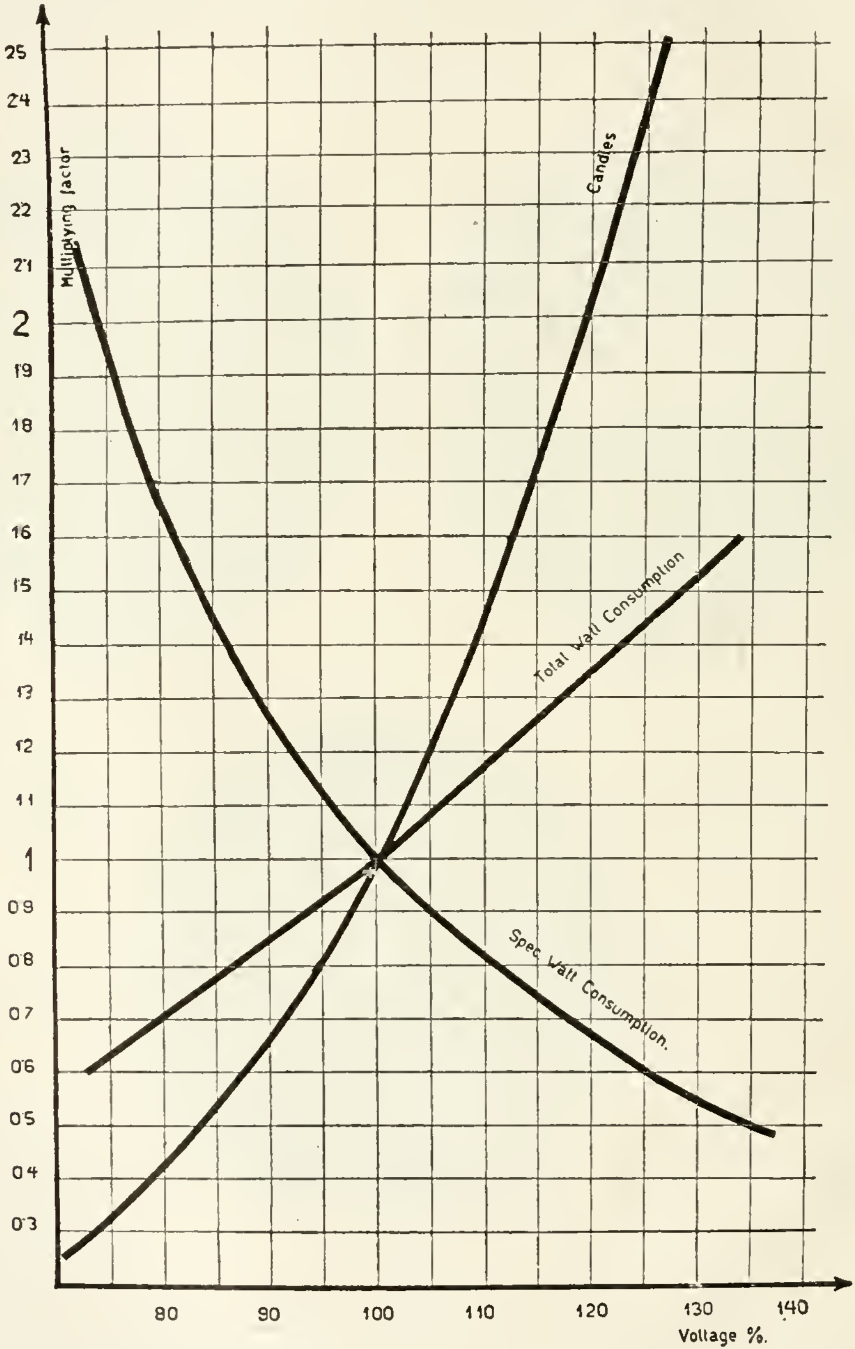

FIG. 15—CHARACTERISTIC CURVES OF THE TUNGSTEN LAMP

then as Wolframite (iron-tungstate) and Hübnerite (manganese tungstate). Its use for special grades of steel is quite well known, and its use in this direction, in comparison tc its use in the incandescent lamp industry, is enormous.

In conclusion a few words may be added with regard to phometering lamps. The tungsten lamp in addition to its great economy of current compared with the carbon lamp has the advantage of being less influenced by varying voltages than the latter. The curves in Fig. 15 show the connection between voltage on the one hand, watt consumption and light intensity on the other hand.* The curve is used in the following way:—starting from a given meaurement, the constant indicated for every other voltage (in percentages of the normal voltage) may be read from the curve, whereupon the normal candle-power and the normal watt consumption respectively are multiplied by the constant in question. Thus the values belonging to the desired voltage are obtained.

The normal rating of a lamp is, for instance, 110 volts, 32 c.p., 1.12 watt, 35.84 total watts. The measurement is required for 99 volts, that is 90 percent of the voltage. The constant for the luminous intensity according to the curve for 90 percent of voltage amounts to 0.67, therefore, the luminous intensity = 32 × 0.67 = 21.44 c. p.

From the historical statements given it will be seen that the existence of the metal filament lamp is due to Auer von Welsbach. He has been the pioneer not only in the development of the incandescent gas light but also in that of the metal filament lamp, and if the tungsten lamp has today reached a very important position, this must be ascribed to him and he merits our warmest thanks.

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*According to Keil.

PRODUCTION SYSTEMS FOR LARGE MANUFACTURING CONCERNS

A. B. REYNDERS,
Director of Production
Westinghouse Electric & Mfg. Company

This is the seventh of a series of articles on the general subject of works management. Previous articles in this series appeared in the April, May, June, August, September and October issues.

IN every manufacturing company there must be some one to indicate to the customer when he will receive the apparatus he has ordered. In a small concern this person is usually the proprietor. As the concern increases in size, the proprietor, not having the time to familiarize himself with the details of all orders in the factory, delegates the giving of dates of delivery to the foreman or the superintendent. As the business develops into large proportions, there is usually a separately organized production department whose duty it is to furnish these delivery dates to all customers.

As one of the prime functions of such a department is to give dates, it cannot fulfill this function satisfactorily unless a carefully worked out system is followed, based upon an intimate knowledge of the construction of the various lines of apparatus being manufactured. The more nearly guess work is eliminated and instead all orders planned through the various steps of manufacture, taking into account the delivery of material, the sooner will the manufacturing company earn a reputation for living up to its promises and thus attract important business at a profit in excess of that obtained by its competitors.

A system which accomplishes this result must take care of the customer's requirements in two states:—

1—Preliminary to receipt of the contract.

2—After the contract has been obtained.

The foregoing statements are general, and apply to all large manufacturing concerns; while the following description outlines briefly, the system in general use at the East Pittsburgh Works of the Electric Company.

Usually the first knowledge the factory obtains of prospective business is an inquiry from a district office salesman for a price and delivery on some particular apparatus. In order that the advice furnished on this iniquiry may be on record and later connected with the contract, should it be secured, it is usual to have a card made out, known as a production estimate card, which contains a description of the apparatus and the performance required by the customer. This card is given a serial number and forwarded to the engineering department, where features of the mechanical construction, such as new parts, new patterns, drawings, etc., are added. The card is now forwarded to the department in the factory where the apparatus is to be assembled and the length of time required by the factory to manufacture is added. The card is then sent to the sales department who, taking the length of time given by the factory and adding thereto an allowance for shipping, entry of order, etc., quote the total number of days, after receipt of the contract, for delivery of apparatus. No calendar dates are given in this preliminary stage, but only number of days. The reason for this procedure is that usually a contract is not closed immediately, but may require several weeks or even months, and a calendar date can easily be given when the contract is closed.

Immediately upon receipt of a contract at the factory, it is reviewed by the engineering department to see that the various pieces of apparatus specified will operate satisfactorily together and will fulfill the requirements of the contract. Just as soon as this is done and all questions affecting the design and performance are settled, a general or shipping order is entered, itemizing thereon each piece of apparatus wanted by the customer and the delivery date quoted to him. This order is sent to the storekeeper and he indicates thereon all items which are in stock, and enters manufacturing orders for all items not in stock. The general order is then forwarded to the shipper and is used by him to check the items when packing and shipping.

Up to this point the production department is not actively involved, but just as soon as the storekeeper enters a manufacturing order (having the same delivery date specified thereon as is given on the general order), it is taken up by the production department and every movement is followed until the completed apparatus is delivered to the shipper. A manufacturing order is known as a stock order or shop order and is numbered serially. Copies of each order are sent to various sections in the factory and to the engineering department.

The copy for the engineering department is sent to the production clerical force, which follows all the work in that department, who attach thereto a copy of the production estimate card and send both to the designing engineer in charge of the particular apparatus. A date in line with the production estimate card is given when the engineer is to finish his specifications for making the drawings. A "tickler" card is used to follow this date. Just as soon as the engineer completes his work, this same production organization takes the design specifications prepared by the engineer to the drawing offices, where dates are made for all drawings which are new. All old drawings and specifications are sent immediately to the engineering clerks, who write upon sheets a list in detail of all material for making the parts specified on these drawings and specifications, route in detail where each piece is to be made in the factory, and order the necessary blue prints. Copies of these sheets are sent to the storekeeper for ordering all raw material not in stock and at the same time all of the other sheets are sent to the assembly section in the factory, from whence they are distributed to the feeder sections as mentioned below. For the new drawings which are to be made, promises for dates of completion in line with the production estimate are sent to the assembly section of the factory. Just as soon as the new drawings are completed, they are turned over to the engineering clerk, who proceeds to write up the material specifications, etc., the same as for old drawings.

Immediately upon receipt of the information sheets or promises in the assembly section of the factory, the production clerk, starting with the delivery date specified on the order, lays out backward in detail the entire job, and specifies on his layout when each piece of material is to be brought into his section, and a date for completition of work on each piece in such a manner that, assuming each date is to be kept, all pieces will come together at the proper time to meet the shipping date for the complete apparatus. The items on the sheets for the feeder sections are then dated in accordance with the layout and the sheets forwarded to the feeders. The feeder section proceed in the same manner to lay out their work, using the delivery date specified by the assembly section as a basis. This is the most important work that has to be done by the production clerks, as it requires a knowledge of the construction of the apparatus in detail; the length of time required to perform the machining operations, the right time to bring in castings and other raw material, etc. This task can be best realized when one takes a walk through the factory and notices material in all forms and all conditions of completion lying about on the floor and then thinks that each piece must be located and brought through to mate with the other material. Also the work must be so planned that each machine tool and workman will be kept busy at the maximum efficiency.

For the purpose of making the layout in the minimum time, various printed forms are used. To give examples of these forms and describe their details here would be of little general interest. In the many publications on "Scientific Management" or "Efficiency Engineering," forms of almost every conceivable arrangement may be found and, although many of these forms possess merit, there is a great tendency to build up a system of forms only and eliminate the human element of interest and responsibility. It may be stated as a fundamental principle that the use of printed forms in production work is justified whenever time and money are saved. If the work can be executed before it can be planned out on paper, any of the so-called efficiency systems based upon the use of forms, printed in special inks, with one certain kind of type and prescribed sizes and colors of paper, hinders rather than assists production. Time is the best test of any of these paper systems. It matters little who is the originator of the system or who may be interested in its adoption, unless there is real merit, the whole structure gradually changes and the useless appendices fall into disuse.

The proper layout is dependent upon a previously determined sequence of operations and length of time for performing each operation. This work is usually accomplished by one or more men (skilled mechanics or machine operators) by inspecting the drawings or specifications. The best method of doing the work, the sequence of operations, the machine tools best suited, the length of time required for the first operation and each one thereafter, must be determined by them and the results furnished to the production clerk making the layout. In many cases if this information is lacking, the production clerk must rely upon his experience with former jobs of a similar nature.

After all this planning has been performed, it is then necessary to execute the plan. One method in use for accomplishing this consists in furnishing to the foremen a list of the work they are to perform with the dates for the completion of each job. It will readily be seen that this list can easily be prepared from the tickler file or from the diary, which will be described later. Although this method is quite efficient where the foreman

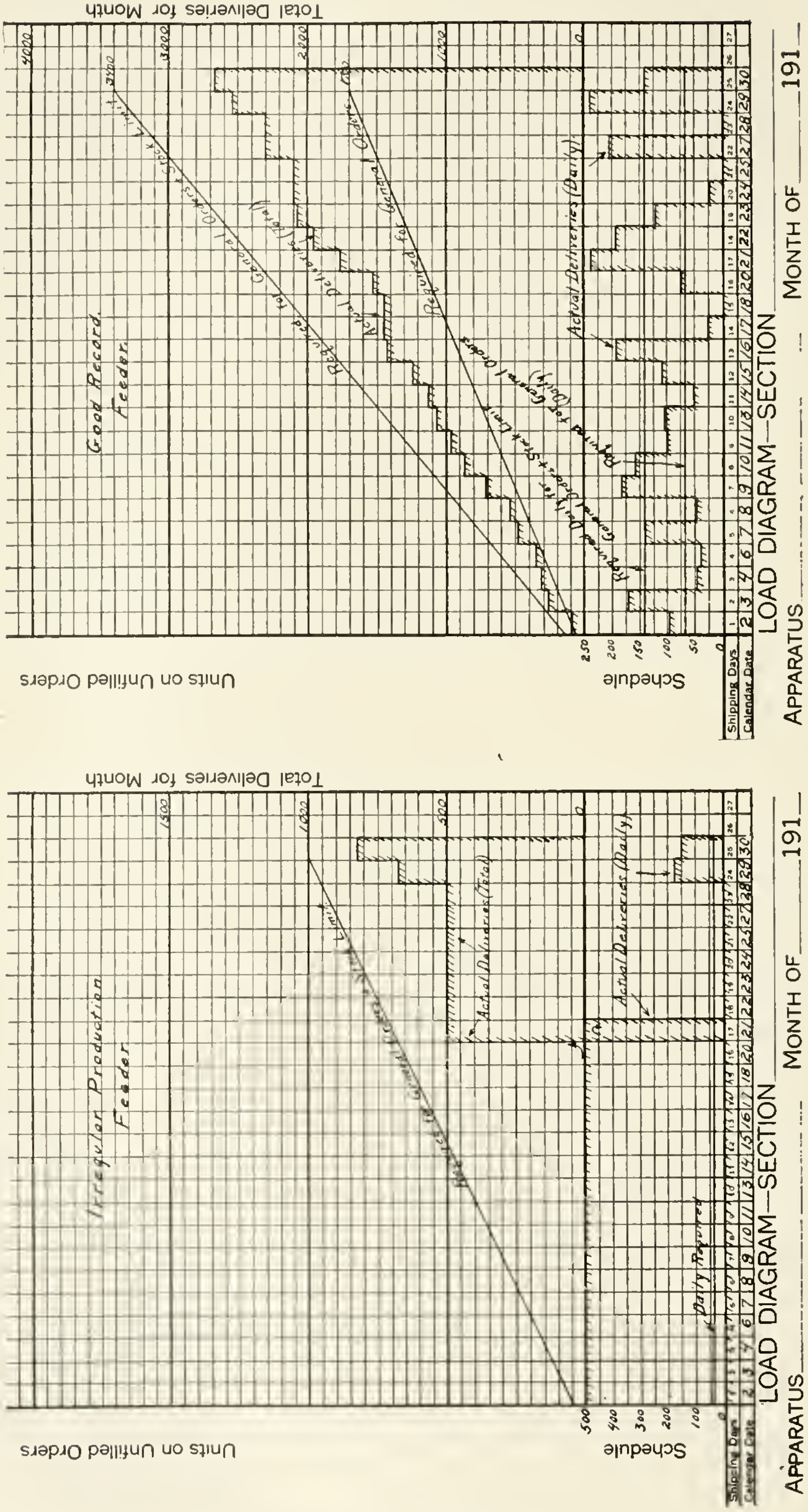


FIG. I—LOAD DIAGRAMS OF FEEDER SECTIONS

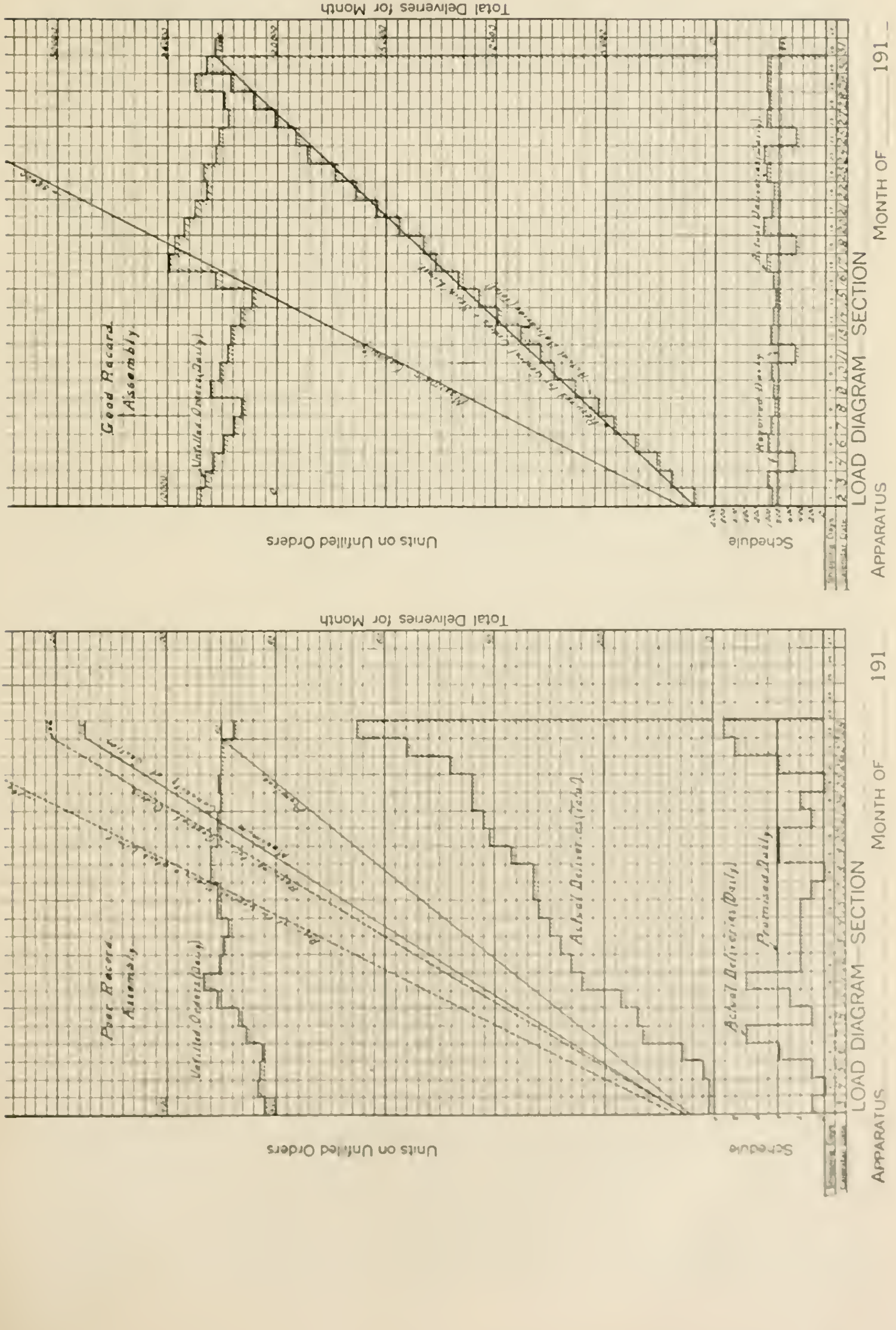


FIG. 2—LOAD DIAGRAMS OF ASSEMBLY SECTIONS

is handling a few orders and has under his jurisdiction but a few men and machine tools, it becomes quite burdensome when the number of orders is large. To handle such a condition it has been found advisable to introduce what is known as the "dispatch board." Briefly, this consists of a board having hooks fastened thereto for each machine tool, bench, vice or operator. The time slips for each operation on a piece are prepared as soon as engineering information is received and are held until the material is received. Just as soon as the material is received, these time slips are dated in line with the layout sheet previously mentioned and all slips for one piece are fastened together and placed on the hook representing the machine tool upon which work is to be started. This set of time slips is arranged on the hook in relation to the other time slips according to the dates on the first slips.` Whenever the workman wants a new job, he goes to the dispatch board and turns in his time slip for the job just completed. The dispatcher, noting the machine tool number on the old slip, removes from the hook on the board bearing the same number, the remaining time slips of the set and hands to the workman the first slip for the next set on the same hook, as the next job. The old time slip is turned over to the timekeeper and the remaining time slips of the set are transferred to the hook representing the next machine tool. By this means the foreman is relieved of all clerical work in assigning jobs to the workman. Moreover the board offers a quick means to the eye for the foreman to get a comprehensive idea of the amount of work on hand at any time. Again, by adding up the time allowed for performing the operations on all time slips, it is an easy matter to obtain the number of hours work ahead of each machine tool, and thus either obtain additional equipment or requisition the work to other departments to prevent a congestion or the breaking of dates. In the matter of purchasing additional equipment, this feature is of great value, as the actual number of hours work ahead can be obtained instead of relying upon the opinion of some one that the equipment is needed.

The dispatch board is the most spectacular instrument connected with the production system. Its functions and merits have often been exaggerated until in many cases the impression has been obtained that the dispatch board is the whole system and, as soon as it is installed, all difficulties will be eliminated and the whole department will operate like a well cut, well oiled set of gears. This impression has often led to disastrous results and only by the strenuous efforts of experienced and efficient operators has the situation been saved. The dispatch board is only the instrument for executing previously planned work. If the layout is not properly prepared, the dispatch board cannot operate satisfactorily. If the proper support and interest is not taken by the foreman and production clerks in the operation of the dispatch board, it is impossible to obtain results. Instead of the board directing the work on the floor, it will degenerate into a record, following instead of leading the floor.

In addition to a production system which is capable of taking care of the minutest detail, there is wanted by the management and those in charge, some quick method of determining whether the factory is producing the quantity required and if it is producing the right quantity at the right time. Like an advertisement on a bill board, this method must convey the desired information in an interesting manner and without the necessity for any greater mental exertion on the part of the user. Such information is usually available in the office of the director of production and consists of graphical records made up of a series of charts.

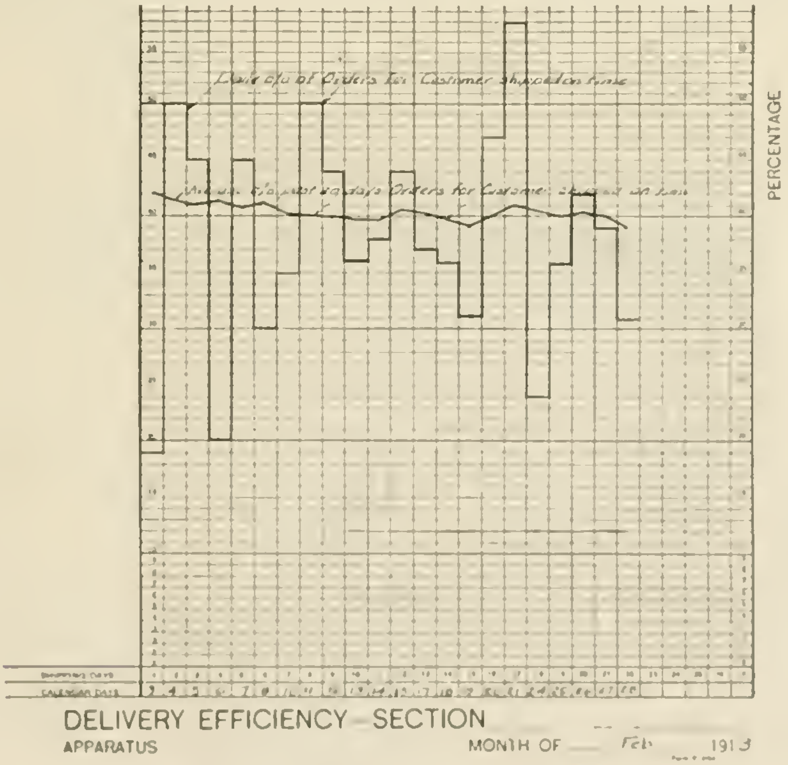
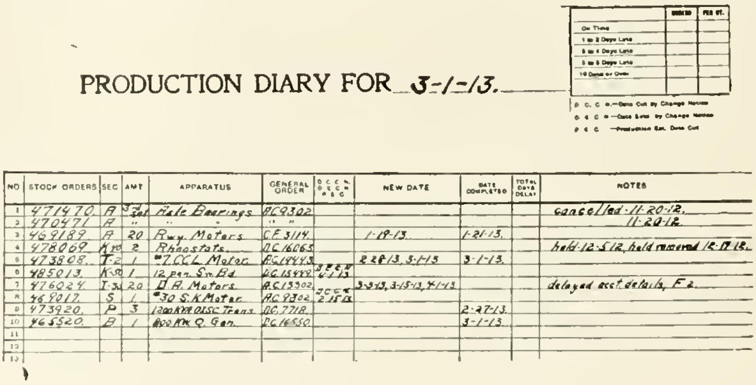


FIG. 3—DELIVERY EFFICIENCY CHART

For outputs, these charts are known as load diagrams and contain lines indicating for each day the total number of units on order not delivered to the shipper, the number of units wanted each day, and the number of units actually delivered each day, as shown in Figs. 1 and 2. For showing how dates given to customers are being met, there is a delivery efficiency chart. On this chart are plotted curves showing the daily percent of dates kept, the average percent of apparatus shipped on time for the past thirty days and the percent of overdue orders on hand, as shown in Fig. 3. Copies of these charts are distributed throughout the various factory sections. Great interest is taken by the superintendents, assistant superintendents, general foremen and foremen in improving the records as plotted daily, and by means of a periodical interchange of records a certain amount of friendly rivalry is stimulated between sections, each striving to excel the other.



PRODUCTION DIARY FOR 3-1-13.

	[illegible]	PER CT.
On Time		
1 to 2 Days Late		
3 to 4 Days Late		
5 to 9 Days Late		
10 Days or Over		

D. C. C. N.—Date Cut by Change Notice
D. E. C. N.—Date Extended by Change Notice
P. E. C. —Production Est. Date Cut

NO	STOCK ORDERS	SEC	AMT	APPARATUS	GENERAL ORDER	D C C N D E C N P E C	NEW DATE	DATE COMPLETED	TOTAL DAYS DELAY	NOTES
1	471470.	A	3 Set	Axle Bearings	AC9302					cancelled 11-20-12.
2	470471	A	"	"	" "					11-20-12.
3	469189.	A	20	Rwy. Motors	CE 3114.		1-19-13.	1-21-13.		
4	478069.	K10	2	Rheostats.	DC16065					held 12-5-12, held removed 12-17-12.
5	473808.	T-2	1	*7 CCL Motor	AC14445		2-28-13, 3-1-13	3-1-13.		
6	485013.	K-50	1	12 pan. Sw. Bd.	AC15449	DECN 4-1-13				
7	476024.	T-3	20	D.A. Motors.	AC13302		3-3-13, 3-15-13, 4-1-13			delayed acct details, F 2.
8	469017.	S	1	*30 S.K. Motor	AC9302	DCCN 2-15-13				
9	473920.	P	3	1200 KVA OISC Trans.	DC7718.			2-27-13.		
10	465520.	B	1	800 KW Q. Gen.	DC16550			3-1-13.		
11										
12										
13										

FIG. 4—PRODUCTION DIARY

The efficiency record is compiled by maintaining in each factory section a diary, which consists of a book having a date assigned to each page, as shown in Fig. 4. All orders due for completion on that day are recorded on the page, and just as soon as they are completed the completion dates are marked thereon. This, it will be readily seen, is equivalent to a tickler which does not advance. A record of this kind in each section very quickly shows the old orders uncompleted and is of great value to the section in getting these orders completed.

SHOP TESTING OF ELECTRICAL APPARATUS—XI

ALTERNATING-CURRENT GENERATORS AND SYNCHRONOUS MOTORS

PRACTICALLY all present day alternators are of the revolving field type, and, while most of the tests described herein are also applicable to the revolving armature type, it will be understood that in the following discussion only the revolving field type of synchronous alternator is considered. The test data in this article is that obtained from a complete engineering test on a 2 140 k.v.a. three-phase, 50 cycle, 6 300 volt, 300 r.p.m. alternating-current generator, which was part of a motor-generator set.

MECHANICAL INSPECTION

Careful mechanical inspection should be made during the erection and first running test of the machine. The collector rings must run true and be smooth and clean; the brushes must be set in the center of the collector rings and so fitted that the bearing surface conforms to the curvature of the rings. When using leaf copper brushes the tension must be adjusted so that the brushes have a sufficient, but not excessive pressure, and the rings should be lubricated occasionally with a very small amount of oil to prevent "cutting." When carbon brushes are used they must be ground in the direction of rotation and the tension properly adjusted.

TABLE I—RESISTANCES

Armature Resistance in Ohms			Field Resistance in Ohms		
Phase	At 16 deg. C.	At 25 deg. C.	Volts	Amperes	At 16.5 deg. C.
1–2	0.0989	0.1024	46.5	69.5	0.697
1–3	0.0991	0.1026	43.5	61.6	0.695
2–4	0.0990	0.1025	40.0	56.8	0.692
			37.3	52.8	0.693

Temperature Coefficient at 16 deg. C.	1.0355
Temperature Coefficient at 16.5 deg. C.	1.0334
Average Armature Resistance at 25 deg. C.	0.1025 ohms
Average Field Resistance at 16.5 deg. C.	0.694 ohms
Average Field Resistance at 25 deg. C.	0.718 ohms

POLARITY

Before the running tests are taken the polarity of the field coils must be checked by any of the methods previously described* that are applicable to synchronous machines.

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*See the JOURNAL for April, 1913, p. 372.

RESISTANCE

Resistances are taken of the field and of the armature windings between all terminals. When taking resistances on the armatures of polyphase machines, care should be taken to place the potential leads on the terminals to which the current leads are connected. The readings in Table I were taken by the bridge method on the armature and by the volt-ampere method on the field. The volt-ampere method is used for taking field resistance so that the field rise of resistance for the temperature test may be readily taken from the last reading on the test if the same meters are used. It is common practice, however, to take field resistance cold and hot by the bridge method as well, for a check. Readings of resistances for the machine used in connection with this article are given in Table I.

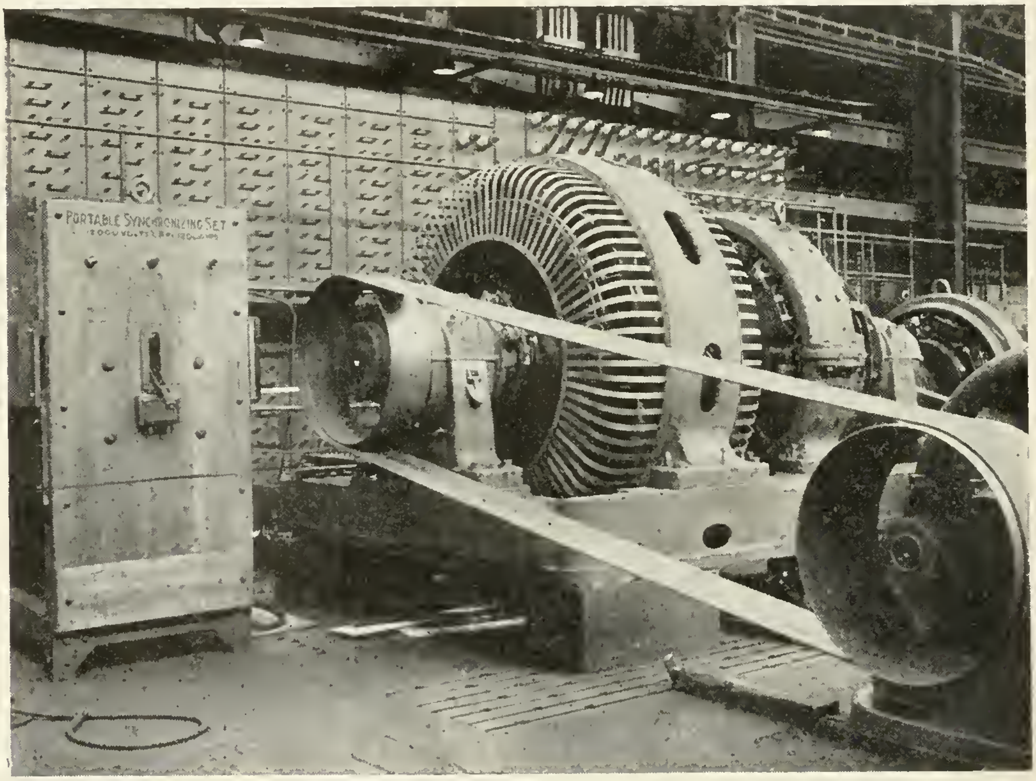

FIG. I—SEPARATE DRIVING MOTOR ARRANGEMENT FOR TESTING AN ALTERNATING-CURRENT GENERATOR OR SYNCHRONOUS MOTOR

CORE LOSS

The core loss of synchronous machines may be obtained by either of two methods, namely; by the use of a separate driving motor or by running the machine as a synchronous motor; the latter should be used only when it is impossible to use the former.

SEPARATE DRIVING MOTOR METHOD

This test is identical with that described for taking core loss on direct-current generators.* Therefore, the same precautions and procedure should be observed.

Core loss should be taken up to the same voltage as the no-load saturation test, but where this is impossible it must be obtained to at least 30 percent above normal voltage. A complete set of readings for a core-loss test together with the curve data derived therefrom is given in Table II. and the resultant curve is plotted in Fig. 2. In working up the core-loss test of alternating-current generators or synchronous motors, the instructions as outlined for direct-current generators should be followed.

FRICTION AND WINDAGE

The friction and windage loss is usually taken after the core-loss tests by the separate driving motor method are completed. The input to the driving motor armature is obtained when running with the belt off at the same impressed armature voltage and field current as used for the no-load reading in the core-loss test. The difference between the input of the motor driving the machine under test with the field and armature circuit of the test machine open, and the motor input with the belt off, is the friction and windage loss.

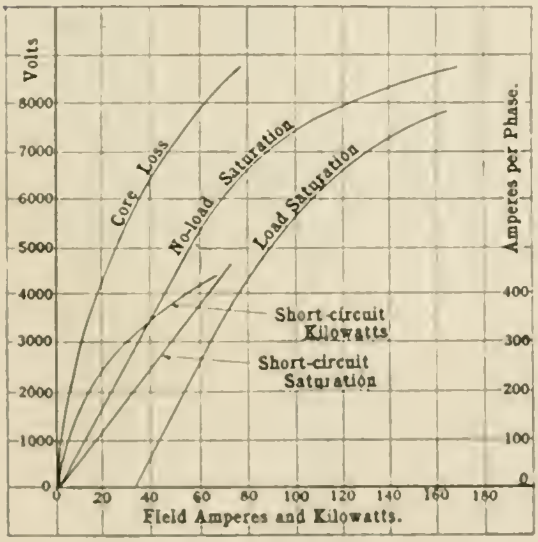

FIG. 2—LOAD, NO-LOAD AND SHORT-CIRCUIT SATURATION AND LOSSES OF A 2 140 K.V.A. ALTERNATOR

Turbo-generators are brought up to speed by coupling them to an extension shaft, which is belted with a large pulley ratio to a suitable motor. The bearing friction and windage of turbo-generators is determined at normal speed, and at 20 percent above and below normal speed. This is obtained by taking readings of the driving motor armature input when driving the generator at the required speeds, and then taking readings of the input to the motor armature running light with the belt off at the same impressed armature voltage and field current as used when driving the machine under test at the various speeds; the difference between the motor input driving the machine and the input running light is the total friction and windage loss; from this result the belt and extension shaft loss must be subtracted to give the true loss of the machine. These "stand losses," as they are called, may be taken from curves previously determined by the separate drive method on the stand alone.

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*See the JOURNAL for April, 1913, p. 379.

TABLE II—CORE LOSS TEST DATA

Driving Motor				Tested Machine		
Reading	Volts	Amperes	Field Amperes	R.P.M.	Volts per Phase	Field Amperes
1	500	143	4.9	301	0	0
2	500	147	4.9	301	1 200	13.2
3	500	158	4.9	302	2 400	26.7
4	500	173	4.9	301	3 600	40.5
5	500	191	4.9	300	4 800	55.5
6	500	143	4.9	301	0	0
7	500	215	4.9	300	6 000	72.5
8	500	221	4.9	300	6 300	77.1
9	500	238	4.85	301	6 930	90.0
10	500	263	4.85	300	7 800	118.0
11	500	288	4.8	299	8 550	155.0
12	500	143	4.9	301	0	0
13	500	22	4.9	—	—	—

Calculated Results and Curve Data

Reading	Increase in Motor Amperes	Testing Machine		
		Kw Core Loss	Field Amperes	Armature Volts
2—1	4	2.0	13.2	1 200
3—1	15	7.5	26.7	2 400
4—1	30	15.0	40.5	3 600
5—1	48	24.0	55.5	4 800
7—1	72	36.0	72.5	6 000
8—1	78	39.0	77.1	6 300
9—1	95	47.5	90.0	6 930
10—1	120	60.0	118.0	7 800
11—1	145	72.5	155.0	8 550
	Decrease in Motor Amperes	Friction and Windage		
1—13	121	60.5 Kw		

CURRENT IN BEARINGS

All alternating-current generators and synchronous motors of over 100 kilowatt output should be tested to determine whether a current due to stray magnetic fields will flow when the circuit between the pillow block and shaft is completed through an alternating-current ammeter and heavy copper cable. The marking of the shaft by the oil rings is an indication of current in the bearings. If the current is appreciable, it is advisable to insulate the bearing or the pillow block.

SHORT-CIRCUIT LOSS AND IMPEDANCE

The short-circuit test is taken to obtain the synchronous impedance and the losses of the machine when running with the armature short-circuited. This test can be taken only with a separate driving motor. The armature is short circuited either through a test table, plug board or series transformers, so arranged that the current in each phase can easily be determined, and the field is connected in series with a high resistance to the exciter, the connections being as indicated in Fig. 3.

After the wiring has been checked and all meters properly connected, the machines are started and brought up to normal speed. They are then allowed to run until the friction becomes constant, as shown by a constant reading of the armature current of the driving motor. After the friction has remained constant for some time, several readings of the armature current at a constant impressed voltage should be taken with no field on the generator while the rotor is neither accelerating nor decelerating; the average of these readings is taken as a basis of calculating the short-circuit loss.

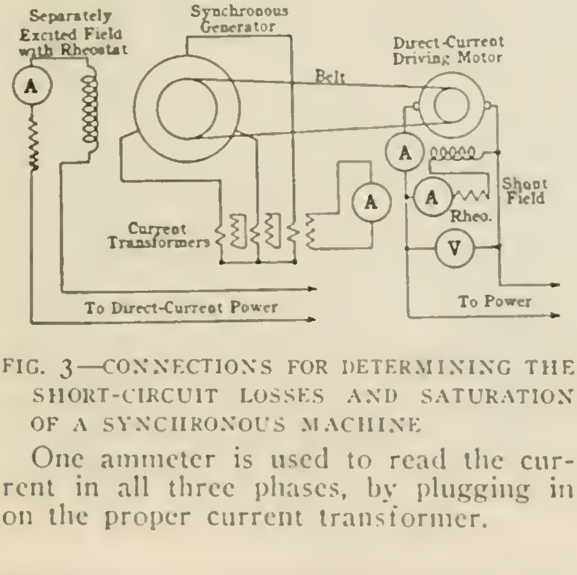

FIG. 3—CONNECTIONS FOR DETERMINING THE SHORT-CIRCUIT LOSSES AND SATURATION OF A SYNCHRONOUS MACHINE

One ammeter is used to read the current in all three phases, by plugging in on the proper current transformer.

The field circuit is closed through a high resistance with close attention given to the armature current; the field current is increased until an armature current corresponding to one-half load is obtained, then readings are taken of the current in each phase, of the field current and speed of the machine on test and of the input to the driving motor and its field current. The field excitation is gradually increased until full-load, load and one-half, and double-load armature current readings are obtained in succession, complete readings being taken at each load. The field current is then opened and a no-load reading is taken to determine whether the friction has changed during the test.

When taking a single-phase short-circuit test on a polyphase machine, the voltage of the open phases should always be measured and recorded, and while the machine is under load the armature connections should be carefully watched for poor joints. The short-circuit loss is calculated from the various driving motor inputs in the same manner as the core loss. The data for this test is given in Table III and the corresponding curves in Fig. 2.

NO-LOAD SATURATION

The no-load saturation is obtained from the readings of field amperes and terminal volts taken while making the core-loss test, by the separate driving motor method. These readings are given in Table II. The saturation should always be taken with increasing field excitation to keep constant the effect of residual magnetism. It should also be taken up to the full-load exciter voltage of the machine under test. If this should cause the voltage to go more than 50 percent above normal the speed must be reduced so that the voltage will not exceed the above limit. The saturation curve is plotted in Fig. 2.

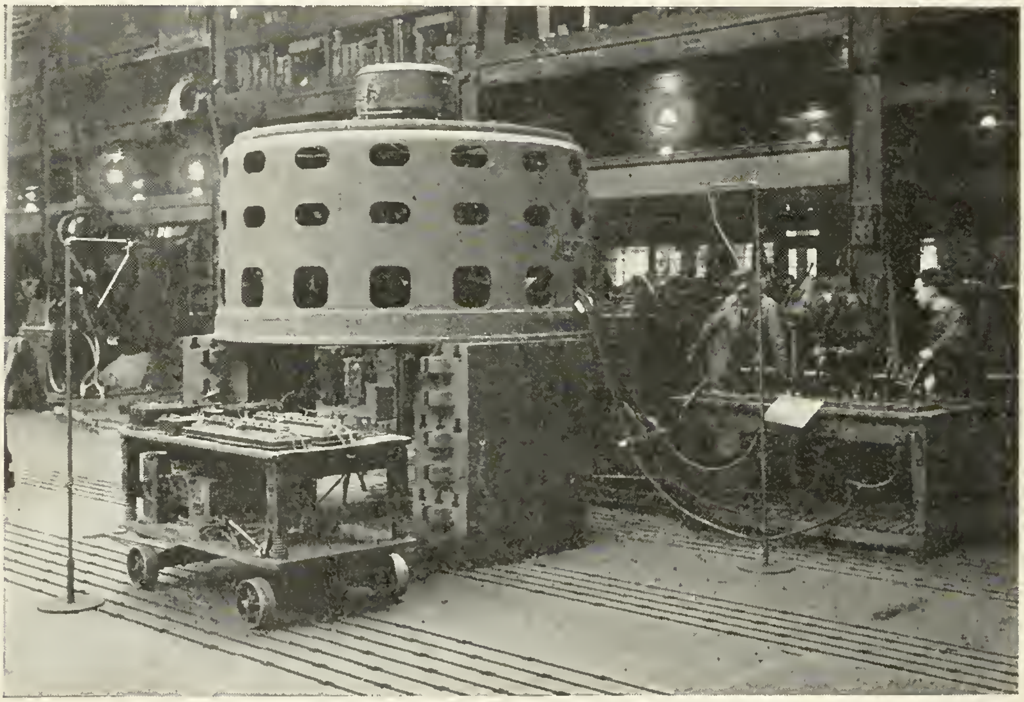

FIG. 4—TESTING A VERTICAL SYNCHRONOUS MOTOR

Resistance wagon in foreground in readiness for resistance readings at completion of test.

FULL-LOAD SATURATION AT APPROXIMATELY ZERO POWER-FACTOR

This test is taken to determine the field excitation required to give full-load current on the machine at approximately zero power-factor. The machine can be run as a synchronous motor or as a generator in parallel with another synchronous machine of similar characteristics, the machines being connected as in Fig. 5. This test should be taken at full-load current. Where it is impossible to obtain this load, it can be taken at some other load available, but should never be taken at less than one-half load, as a test below this is of little value. At each point, readings are taken of terminal volts and amperes in each phase, field amperes and speed. The resistances to control the field circuits should have close regulation and be easily adjustable. It is advisable to have a field ammeter in the field of each machine so that the desired voltage and load can be accurately maintained while the readings are taken. The voltage is then reduced in suitable steps by reducing the excitation of both machines, such a difference being maintained in the excitation of the two as will give the desired value of armature current, a complete set of readings being taken at each of ten or twelve different voltages, including the point at normal voltage. The test need not be carried below 50 percent of the rated voltage of the machine under test. If the machines have about the same rating, the lowest voltage obtainable will be that with no field on the loaded machine. Armature volts and amperes are read for each phase, the values being given in Table IV. In this table, however, only average values of armature volts and amperes are recorded. For convenience the readings given in Table IV are plotted on the same curve sheet as the no-load saturation curve, Fig. 2.

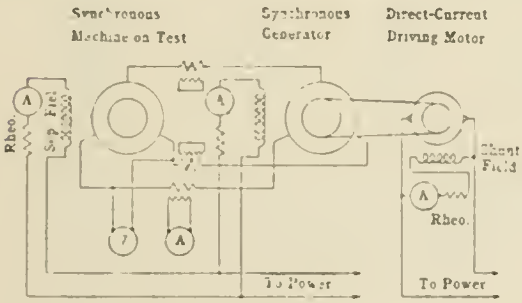

FIG. 5—CONNECTION DIAGRAM OF THE ARRANGEMENT USED IN OBTAINING THE FULL-LOAD SATURATION AT APPROXIMATELY ZERO POWER-FACTOR

One ammeter and one voltmeter are ordinarily used to read the current and voltage of all three phases.

The straight part of the load saturation curve at approximately zero power-factor should be parallel with the straight part of the no-load saturation curve and the no-voltage point on the former curve corresponds to the field amperes obtained at the same armature current on the short-circuit test. This is indicated at *F* in Fig 6. If the tested values of the field current obtained at the lower voltages do not fall on the straight line nor parallel to the no-load saturation curve, it is due to the fact that at low voltages the power-factor cannot be held near zero, except when some mechanical power is applied to provide for the losses and so reduce the energy current to zero.

The load saturation at zero power-factor may be checked with the no-load saturation in the following manner: In Fig. 6 first construct the triangle *CDE* by laying off on the normal voltage line from the point *D*, a horizontal distance *ED* equal to the short-circuit field amperes *OF* at the base of the curves. From the point *E* draw a line *EC* parallel to the air-gap line *OG*, intersecting the no-load saturation curve at *C*. Connect points *C* and *D*. Then, at any point on the load saturation curve the length of a line drawn parallel to *CD* between the two saturation curves should always equal *CD*. In some machines, due to peculiarities in design, the no-load and load saturation curves will not check as here described, but the exceptions are so few that a discussion of them will not be taken up here.

TABLE III—SHORT-CIRCUIT LOSS AND SATURATION

Driving Motor			Machine on Test			
Volts	Amperes	Field Amperes	R.P.M.	Average Amperes per Phase	Field Amperes	Short-Circuit Loss, Kw
500	143	4.9	302	0	0	0
500	150	4.9	302	99	15.3	3.5
500	170	4.9	301	195	30.0	13.5
500	202	4.8	299	294	46.0	30.0
500	250	4.75	300	390	60.5	53.5

TABLE IV—DATA FOR FULL-LOAD SATURATION TEST AT ZERO POWER-FACTOR

Armature Volts	Average Amperes per Phase	Field Amperes.	R.P.M.
3 600	196.2	71.0	300
4 800	196.2	86.5	298
6 000	196.2	106.0	300
6 300	196.5	112.0	301
7 200	196.0	138.5	300
7 590	195.8	155.0	299

LOCKED SATURATION

On all synchronous motors of new design, with a squirrel cage winding distributed through slots in the pole faces, a locked saturation is taken to determine the starting characteristics. Due to the salient field pole structure on which the cage winding is placed and to the distribution of the stator windings, there is often a distinct series of places known as points of maximum and minimum torque. These points can be determined either by weighing the torque at a given voltage for the various rotor positions, or by determining the points of maximum and minimum currents at a given voltage and various rotor positions, the maximum current showing the point of maximum torque.

When taking a locked saturation or starting test the field circuit must always be closed through a resistance, because of the high voltage otherwise induced in the field windings, and the total resistance of the closed field circuit should be approximately such that normal exciter voltage will force through it the field current required at no-load normal voltage. The locked current readings should be taken up to at least three times full-load current, whenever possible, with the rotor in the maximum and minimum positions, but the windings must not be allowed to reach an excessive temperature.

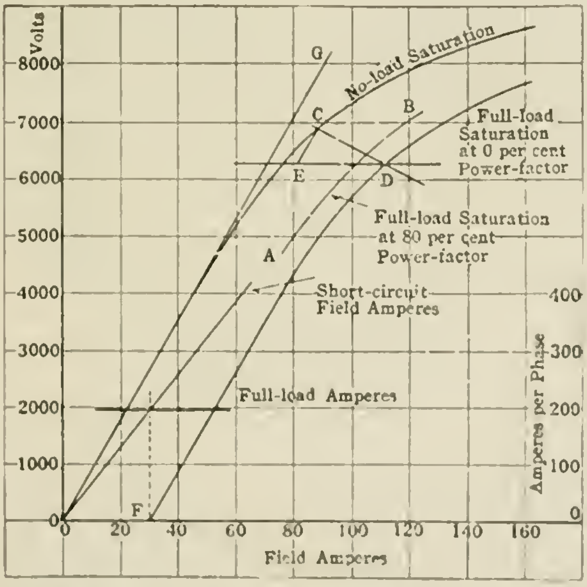

FIG. 6—METHOD OF CONSTRCTING A SATURATION CURVE FROM THE NO-LOAD, AND FULL-LOAD ZERO POWER-FACTOR SATURATION CURVES

When the motor cannot be turned readily by hand, it should be locked. The power circuit is then closed and the voltage on the line slowly increased until approximately full-load current is flowing in the windings. Readings are then taken of the volts, amperes and watts in each phase. The power is then disconnected and the rotor moved a distance equal to that between two armature slots and another set of readings taken at the same voltage as in the first trial. Readings are taken at corresponding positions for each armature slot over a distance equal to that from center to center of adjacent poles. From the readings as obtained above, the rotor is set on the point giving the lowest torque, and readings are taken at various voltages up to such a value as will give approximately three times full-load current. The rotor is then moved to the position giving the maximum torque and another complete set of readings is taken at various voltages.

When the rotor is not too heavy to be turned easily, the maximum and minimum points may be found by applying a low constant voltage on the armature and watching the ammeter closely as the rotor is moved the distance from center to center of adjacent poles. The points of maximum and minimum current should be marked and a complete set of readings taken as noted above.

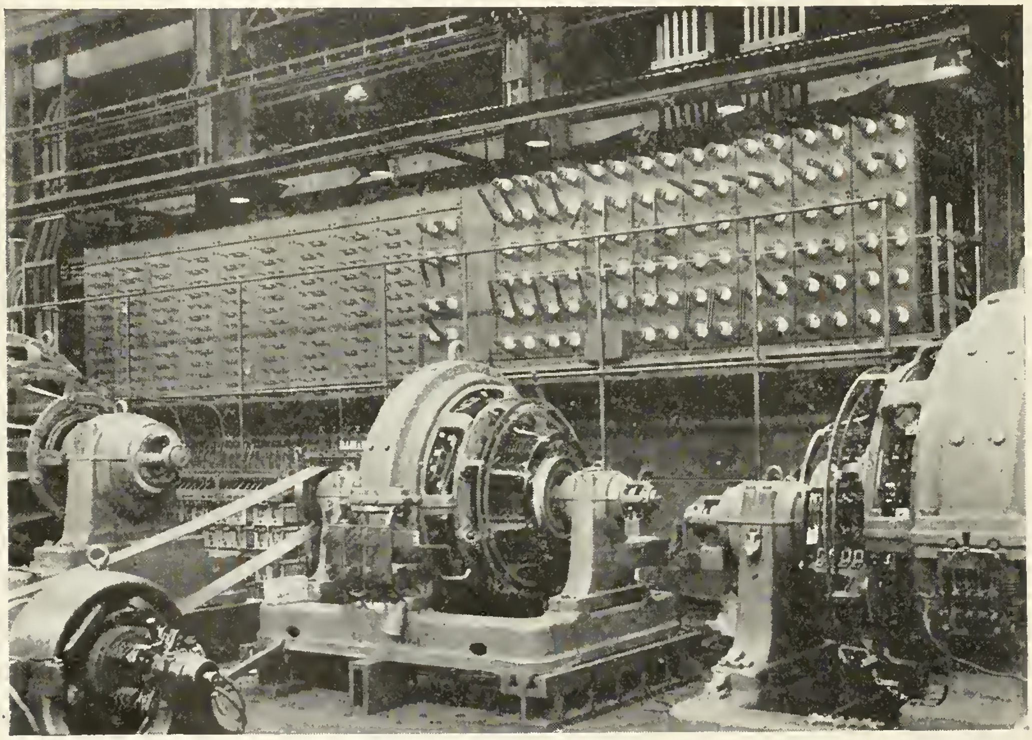

FIG. 7—A CORNER OF A TYPICAL TEST FLOOR SHOWING IN THE BACKGROUND THE SWITCHBOARD FOR THE REGULATION OF THE POWER USED

When taking the readings of torque, the brake arm should be tapped with a hammer or mallet to overcome the static friction of the bearings. The brake arm should be counter-balanced and clamped directly to the shaft, and should be as light as possible, so that the additional weight on the shaft is no more than is absolutely necessary. Should it be necessary to run the machine between readings to cool it off, the position of the rotor must be marked so that it can be returned to the correct position. Table V gives a complete set of readings for this test and the resultant curves are plotted, as indicated in Fig. 8.

STARTING TESTS FOR SYNCHRONOUS MOTORS

A starting test to determine the current and voltage required to start the machine should be made after it has been at rest for at least twelve hours in order to approximate normal starting conditions as nearly as possible. On self-starting synchronous motors the field circuit should be closed through an external resistance of the same value as used in the locked saturation test. The starting transformers may or may not be used in the starting test, depending on the machine's guarantee specifications. When connected directly to the power circuit, the voltage of the generator must be easily controllable. The line switches are closed and the voltage on the line gradually increased until the machine starts; a reading of the voltage and current is taken and the power immediately cut off. Such readings are taken for positions corresponding to each armature slot, as for the torque test. The first position is checked to show the difference with the bearings lubricated and not lubricated. After these readings have been obtained, the voltage required to start the machine is applied and held constant and the time required for the machine to reach synchronous speed, as shown by the sudden drop in armature current, is noted. This test can be made with the machine alone or belted to a generator as an inertia load.

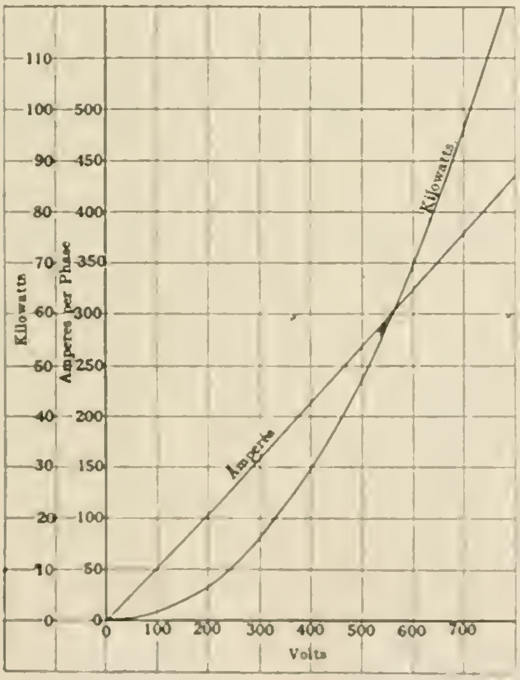

FIG. 8—LOCKED SATURATION CURVES OF A SYNCHRONOUS MACHINE

When the machine is connected to the starting transformers the line voltage must be held constant at its normal value throughout the test. The machine is first connected to the low-voltage taps of the auto-transformer and the starting switches closed; if the machine does not start, the power circuit is opened and the leads changed to the taps for the next higher voltage to repeat the test. This should be continued until the correct taps are found. If the machine does not start with the transformer connected at the highest voltage taps, the line voltage is increased until the machine does start. This voltage is recorded as the motor starting voltage. When the correct starting point has been obtained the voltage is held constant and the time required for the machine to reach synchronous speed is recorded. Several starts are made in rapid succession and the heating of the auto-transformers is noted. With the auto-transformers connected as before, the primary voltage is increased slowly until the motor starts and readings are taken of primary volts, primary amperes and secondary volts at the moment of starting. The motor is then locked and the primary voltage raised to the full rated value, readings being taken of primary volts, primary amperes and secondary volts. With the secondary of the starting transformer open and the full rated voltage on the primary, the secondary voltage of each tap is read.

TABLE V—DATA FROM LOCKED SATURATION TEST

Average Armature Volts	Average Amperes per Phase	Total Kw
200	99.0	6.4
400	214.0	30.0
600	322.5	69.6
800	433.0	126.4

When a separate starting motor having a squirrel-cage secondary is supplied with the machine, it should be connected directly to a circuit the voltage of which can readily be controlled. Several starts are made and readings are taken each time of the volts and amperes on one phase. With normal field on the machine, it is brought to the rated speed with rated voltage on the starting motor. The test is then repeated at the minimum voltage which will start the machine. Next a locked saturation test is taken on the starting motor with readings of volts, amperes and watts. If the motor has a wound secondary its control apparatus must be connected in the circuit. The voltage of the line should be held constant at the normal value, and the motor started through its controller and resistance.

TABLE VI—MODIFIED ELECTROMOTIVE-FORCE METHOD OF CALCULATING REGULATION

Assumed Field Amperes	Terminal Volts* No-load	Terminal Volts* Full-load, Zero Power-Factor	Total Drop in Volts
(1)	(2)	(3)	(2) - (3)
80	6 480 (cf)	4 340	2 140 (Oc)
100	7 300 (be)	5 670	1 630 (ab)
120	7 870 (ad)	6 600	1 270 (Oa)

*Taken from curves. Fig. 5.

As the starting motor is of the induction type with its inherent slip, it is necessarily wound with a smaller number of poles than the synchronous machine. This may give it a speed considerably above the synchronous speed of the larger machine. If the no-load losses of the larger machine are are not sufficient to hold it down to its synchronous speed, additional external load must be applied to maintain the required slip throughout the test. This load should be recorded on the sheet.

TORQUE TESTS

Self-starting synchronous motors usually have a squirrel-cage damper winding on the rotor with either copper, brass or steel bars. The starting torque, pull-in torque and pull-out torque tests should be taken whenever guarantees have been made, or complete information is required.

Starting Torque, is that which the machine will develop when operating at a reduced voltage as an induction motor with the field short-circuited, as in the locked saturation test. A prony brake or beam clamped on the shaft is used for weighing the torque. The length of the arm must be carefully determined, this being measured from the center of the shaft to the point of contact on the scales; the tare also must be accurately determined by suspending the brake or beam from a point directly above the center of the shaft and weighing the amount supported by the scales. The machine is connected the same as for the starting test. The rotor is locked in the position of minimum torque which corresponds to the minimum ampere point, as previously determined by the starting test, and the field is short-circuited through a resistance sufficient to give the normal field current. Sufficient voltage is applied to the machine to determine the connection which will give the proper direction of rotation; the brake or beam is tightened up sufficiently to lock the rotor and the voltage is brought up to as high a value as possible without injury to the machine. The torque impressed on the scale is then balanced and read. The voltage at this instant is noted and the power is then taken off. In order to avoid overheating, the power should be on only for a sufficient length of time to obtain these readings. The operation is repeated with seven or eight different voltages in five percent steps. Then the voltages and torque should be measured with the rotor in the different positions over the pole arc as called for in the startings test.

The torque readings taken in the same position of the rotor may be checked with each other by assuming that the torque varies directly as the square of the voltage at which it is taken. This as sumption may be expressed by the equation,* $T_1 \div T_2 = V_1^2 \div V_2^2$.

Pull-in Torque —The purpose of this test is to find the maximum load that the motor will carry while changing from an induction motor to a synchronous motor. It can best be obtained by belting the motor to a direct-current generator of known efficiency connected to a resistance load. The field of the generator should be separately excited so that the load can be adjusted quickly and accurately. The motor is connected as in the starting-torque test, except that a double throw switch must be provided for handling the field circuit. This switch should be arranged so that the field of the machine can be changed quickly from a short-circuit to an exciter circuit, with such resistance that the field current will be normal. Readings of terminal volts, terminal amperes and speed on the synchronous machine are taken and of armature volts and amperes on the generator. The efficiency curve of the direct-current generator used and the pulley sizes on each machine are recorded.

With the field short circuited, the voltage is increased until the machine starts. After it is up to the speed, the voltage is held constant at a value which will give 25 percent of full-load torque at starting as determined from the starting-torque test. Sufficient load is then applied to the generator to produce an appreciable slip of the motor and a complete set of readings is taken; the field is changed from the short-circuit to the exciter circuit and the same readings taken as before, the maximum kick of the meters being noted at the moment of changing over as well as the final values. The time taken for the machine to pull into synchronism is recorded, the load is increased and the test repeated until a load is reached at which the motor will not pull into synchronism.

To make this test complete it should also be taken at one-half, three-fourths and full voltage if possible. Also, the effect of varying the field current is tried to ascertain if there is any difference in the amount of pull-in torque.

Pull-out Torque, of a synchronous motor is that at which it will pull out of synchronism at normal voltage and 100 percent power-factor. If it is impossible to run the test at normal voltage, because of inadequate loading apparatus, the test can be taken at a lower voltage, and the pull-out torque at normal voltage is then determined by the relation $T_1 : T_2 = V_1^2 : V_2^2$, where T_1 and T_2 are the respective torques and V_1 and V_2 the corresponding voltages.

The machine is belted to a calibrated generator and connected as in the pull-in test; or, on the smaller sizes a prony brake may be used. To gauge the capacity of the loading apparatus, one-half normal voltage is first applied to the motor, the field is adjusted for approximately 100 percent power-factor, and the load is increased until the motor falls out of step, readings being taken of load on the generator, and voltage, watts and field current of the motor. The torque can be calculated from the pulley ratio and the calibration of the generator. The test is then repeated with various field currents producing both lagging and leading power-factors, and a curve is plotted of field current against pull-out torque, from which the maximum torque may be determined.

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*This is not strictly true but serves as an adequate check between two tests.

This test is then repeated at full voltage, (or if sufficient load be not available, at as high a voltage as pull-out can be obtained without injury to the motor from excessive currents) for the field current which produces 100 percent power-factor, and for enough other values to determine the maximum pull-out torque. The values calculated from the tests at one-half voltage serve as a check on the actual values secured at normal voltage, or calculated from a test at any lower voltage.

REGULATION OF ALTERNATING-CURRENT GENERATORS

The regulation of alternating-current generators can be determined by test with actual load conditions or it may be calculated. The latter method is used in practically all cases on account of its convenience and because results are more accurate than can be obtained under the ordinary methods of testing.

There are various methods of calculating the regulation of synchronous generators. Two methods commonly used are the modified electromotive-force method and the magnetomotive-force method.

Regulation by Modified Electromotive-Force Method—This is the most accurate of the various methods and, although it is somewhat longer and more tedious to use, the greater accuracy of the results obtained warrant the additional time required. The calculations as shown herein are for over-excited fields only. The tests required are the no-load saturation, the full-load saturation at approximately zero powre-factor and the short-circuit saturation. Since it is impossible to determine directly the exact excitation at any desired load, voltage and power-factor, it is necessary to determine a partial saturation curve of at least three points at the desired load and power-factor passing through the normal voltage line on the curve. The calculated curve *AB*, Fig. 6 at full load 80 percent power-factor is determined as follows:—

From the load saturation curve at approximately zero power-factor, take values of field current as in Table IV such as will cause the desired curve *AB* to pass through the normal voltage line. On a rectangular co-ordinate sheet (Fig. 9) take a base line *AOB* and, with *O* as center, draw the quadrant of a circle with a radius of 100 parts, the vertical line *OC* being the measurement of the power-factor. On this circle *CDB* lay off the desired power-factor 80 percent, at *D* and draw a line connecting *O* and *D*. Divide the lines *AO* and *OB* into any convenient scale of volts starting from *O;* lay off on *OD* the values of the total drop in volts, *Oc, Ob,* and *Oa,* corresponding to the values of field amperes chosen. From the point *a* draw a line *ad* with a value equal to the terminals volts at no load, intersecting the base line at *d;* the value of volts (7 040) as measured from *d* to *O* will be the total volts obtained with full-load current in the armature at 80 per cent power-factor and a field excitation of 120 amperes; proceed in the same manner with the points *b* and *c,* measuring the resultant voltage on the base line *AO.* Then for field excitations of 80, 100 and 120 amperes with full-load current at 80 percent power-factor, the respectivv voltages will be 5 000 (*Of*), 6 200 (*Oe*) and 7 040 (*Od*). These values are plotted as shown in Fig. 6 giving the load saturation curve *AB*. The intersection of this curve with the normal voltage line determines the field current (101.5 amperes) required to maintain normal voltage (6 300) with full-load current at 80 percent power-factor; with 101.5 field amperes the no-load voltage is 7 350 volts. The percent regulation at the above load, therefore, is — $(7350 - 6300) \div 6300 \times 100 = 16.7$ percent.

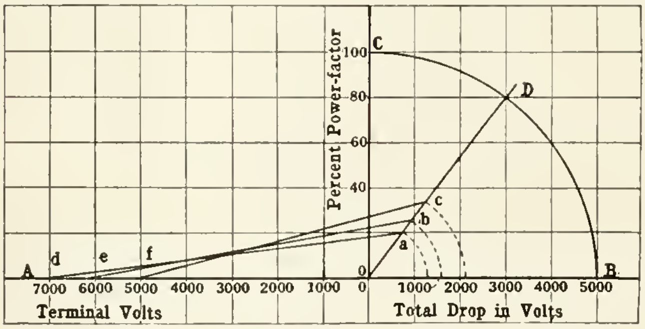

FIG. 9—CALCULATION OF THE REGULATION OF A SYNCHRONOUS MACHINE AT ANY POWER-FACTOR BY DIAGRAM

This construction is approximately correct for all values of power-factor below 90 percent; but above 90 percent it is necessary to take the ohmic drop into consideration as follows:—Subtract the ohmic drop at full-load current from the values of terminal volts as found on the base line *AO*, measured from *O* to *d, e* and *f*. This will give the terminal volts with full-load current in the armature at the assumed values of field current.

If the regulation be desired on any other load than that at which the load saturation was taken, it is necessary to calculate another load saturation curve at the desired load. The distance between the curves on the line *CD*, Fig. 6, or any line parallel to *CD*, is proportional to the load, and *CD*, being drawn between the no-load and full-load saturation curves, represents the 100 percent range for such curves. From this relation, points on the zero power-factor load saturation curve at any other load can easily be obtained by laying off on the line *CD* and lines parallel to *CD* from the no-load saturation curve the value corresponding to the desired load.

When desired for efficiencies only the field current at other loads then those obtained in the test can be readily determined. In Fig. 10 on the line *OD*, lay off the total voltage drop *Oa* (1 600) for full load at approximately zero power-factor at the same field current (101.5 amperes) as obtained for full load at 80 percent power-factor normal voltage. *Oa* is obtained from the curves in Fig. 6 as follows:—

TABLE VII—DATA FROM FIG. 10 FOR THE DETERMINATION OF FIELD CURRENT BY CALCULATION

Percent Load	No-Load Volts	Field Amperes
0	6 300 (Ob)	77
25	6 550 (cb)	81.5
50	6 800 (db)	86.5
75	7 000 (eb)	94
100	7 350 (ab)	101.5
125	7 660 (fb)	112

Terminal volts, no load, at 101.5 field amperes..........	7 350 (*a b*)
Terminal volts, full load, zero power-factor 101.5 amperes	5 750
Total drop volts, or difference of these two value......	1 600 (*O a*)

Divide the distance *Oa* into equal parts for each quarter load up to the desired over-load. The distances as measured in volts from the points *c*, *d*, *e*, *a*, and *f* to *b* will be approximately the no-load voltages required to give the normal voltage at 80 percent power factor at their respective loads, and the field currents can be read from the no-load saturation curve. The no-load voltages and their field currents are given in Table VII. This method for obtaining the field current at fractional loads is only approximately correct when the normal voltage comes on the bend of the saturation curve, but when the normal voltage falls on the straight part of the curve, the results are within the limits of engineering accuracy.

The Magnetomotive-Force Method is accurate when the entire working range of field excitation is on the straight part of the no-load saturation curve. The values of field excitation for 100 percent power-factor will be very nearly accurate and will check with the results obtained by the modified electromotive-force method; but at power-factors other than 100 percent, the excitation will be considerably lower than that actually required.

The method of construction is the same as that outlined in Fig. 10, except that the base line is divided into a convenient scale of field amperes instead of terminal volts. To obtain the field current at any desired load and power-factor lay off in Fig. 10 on the line *OD,* drawn from the desired power-factor, the value of field amperes required to circulate the desired load amperes with the armature short-circuited. On the line *OA,* lay off to the same scale the value of field amperes required to give the sum of normal voltage at no-load position, and armature ohmic drop (for the desired load); the geometric sum of these field currents as represented by the line *ab,* will be the field at the desired load and power-factor. Then, having the values of field current, the percent regulation is obtained in the same manner as for the assumed values in the modified electromotive-force method.

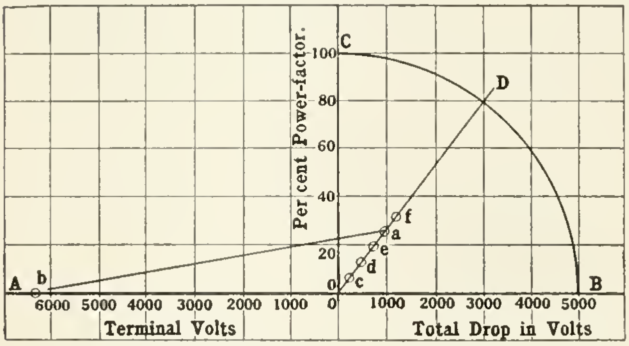

FIG. 10—CALCULATION OF THE SATURATION CURVE OF A SYNCHRONOUS MACHINE AT ANY POWER-FACTOR BY DIAGRAM

The short-circuit armature current is directly proportioned to the field excitation at low saturations; therefore, the field current for any other load at the same power-factor can be obtained by laying off on the line *OD* the value of field current directly proportioned to the value of the desired load.

For synchronous motors the construction is the same, except that there is laid off on the line *OA* the value of field amperes at no load which is required to give normal voltage minus the armature ohmic drop at the desired load

Algebraically, the regulation by this method is calculated as follows: Let Iw = the watt component of the field current (the field current corresponding to no-load normal voltage plus the armature IR drop from the no-load saturation curve); Io = the wattless component (the field current corresponding to the armature load amperes from the short-circuit saturation curve; and PF = the power-factor expressed decimally. Find the vectorial sum of Iw and Io at an angle of 90 degrees minus $\mathrm{Cos}_{-1}\,PF$. Thus, the vectorial sum = $\sqrt{\left(I_w + I_o\sqrt{1-PF^2}\right)^2 + \left(I_o \times PF\right)^2}$ Then the percent regulation equals 100 $(E_1 - E) \div E$, where E_1 = the voltage corresponding to the vectorial sum of the field amperes, taken from the no-load saturation curve, and E = the rated voltage of the machine.

(To be continued.)

THE JOURNAL QUESTION BOX

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975—Oil Circuit Breaker—A 2 500 k.v.a. station supplies power to a 44 000 volt, three-phase line (generated voltage 2 300), by two generators, each connected to its own three-phase transformer. From the transformers the line passes directly out of the station without any oil switches intervening. An electrolytic lightning arrester protects this line and each transformer is fed from a board through an automatic circuit breaker. Is it good practice to omit oil switches between the line and transformers when the station supplies only one circuit? Will the arrester alone take care of any surges that may come in over the line?

R. C. W. (TENN.)

On the score of economy oil switches are not required on the high tension side of the transformers, although the two banks feed into a single line. However, on the score of convenience it may sometimes be desirable to have oil circuit breakers on the high tension side of each transformer, as then failure within the transformer would not be a means of shutting down the whole plant. This is pretty well taken care of by the automatic circuit-breakers on the low tension side of the same transformer, assuming that disconnecting switches are provided on the high tension side as now installed. In general, it would be considered good practice to omit the oil switches in such a case if the high tension disconnecting switches referred to are provided. The electrolytic arrester connected directly to the high tension line outside of the substation will provide protection against most surges likely to occur. If the line is provided with an overhead ground wire the protection is still more perfect. However, with a direct stroke of lightning, the arrester may not be adequate to protect the transformer. The use of the generators, transformer and line as a complete unit is commonly advocated where the rest of the installation permits. In this way no switches at all need be used from the generator clear through to the far end of the transmission line. There should be, perhaps, a few non-automatic switches in the nature of disconnecting units.

K. C. R.

976—Measurement of Polyphase Current—We have transformers connected as shown in Fig. 976 (a) with cross connections from our 220 volt, three-phase bus-bars to the 110 volt, three-phase bus-bars. This connection was made because the inside delta connection was over loaded. We still have three-phase, 220 volt load composed of wires *1*, *2* and *3*; also a 110 volt, three-phase load composed of lights and motors on wires *4*, *5* and *6*. *X* is on wires *4*, *3* and *6*, *Y* is on *1*, *4* and *5*, while *Z* is on *6*, *5* and *2*. The meter on the 220 volt bus is five amperes, 200 volts polyphase with two 1600/5 current transformers and on the 110 volt bus is five amperes, 100 volt with two 600/5 current transformers. Please give all the data you can on this connection. Is the company losing or the consumer paying for current he is not getting?

J. G. W. (CALIF.)

Meters connected as shown in Fig. 976 (a) will register correctly the power used in the outside delta and the power in the inside delta, but will not register correctly the power taken from the two sets of lines. In other words, the power in circuits *X*.

Y and *Z* will not be correctly registered. Thus, in case *X*, the voltage and current in both the elements of meter No. 1 will be 90 degrees out of phase at unity power-factor and will fall more closely in phase as the power-factor decreases. In both cases *Y* and *Z*, part of the current will be measured by meter No. 1 at the correct voltage, while part of it will be measured by meter No 2 at double the correct voltage, although the phase angles will be wrong in both cases depending on the power-factor of the load. The chances are that the central station is losing, although there are certain conditions of load and power-factor, whereby a customer might be paying for more current than he is using. All the energy used will be correctly measured by six single-phase or three polyphase meters connected as in Fig. 976 (b). W. B.

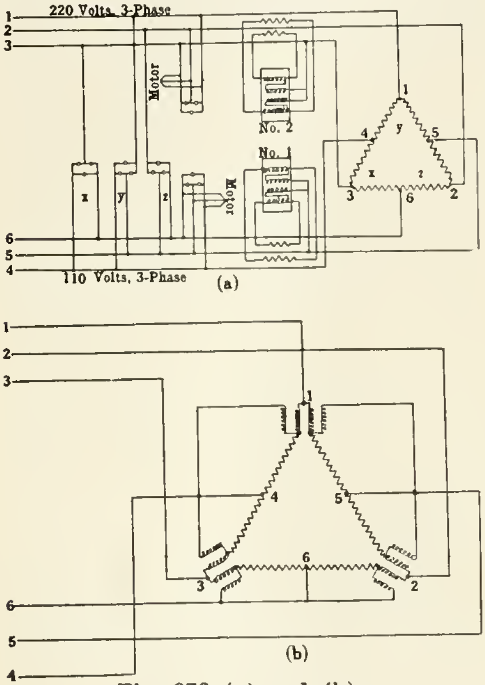

Fig. 976 (a) and (b)

977—Two-Phase to Three-Phase Transformation—In an industrial plant using two-phase and three-phase 550 volt motors, the method of power transmission shown in Fig. 977 (a) is used. (a) Can the phase relation of such a line be represented graphically? (a) What would happen if the two-phase load was heavier than the three-phase? (c) If the three-phase and two-phase motor loads have a power-factor of 80 percent respectively, what is the resultant power-factor of the line?

G. C. C. (QUEBEC)

(a)—The phase relations of such a line are indicated in Fig. 977 (b). This method of power transmission is thoroughly practicable. (b)—A two-phase load or a three-phase load may be taken from the secondary separately or in any possible combination and the primaries will still remain balanced, provided the two-phase and three-phase secondary loads are each independently balanced. (c)—The resultant power-factor of the line will be 80 percent. See also Nos. 959 and 947. C. F.

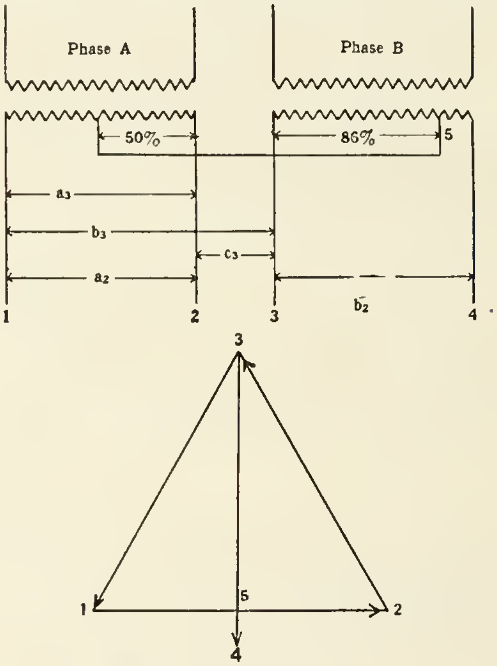

Fig. 977 (a) and (b)

CORRECTIONS

Lines 13, 14 and 15, p. 610 of the June, 1913, issue, should read "After starting one set, any two of the leads from the induction motor of that set which, of course, will be running as a generator, should be connected to two terminals of the three-phase line, and the voltage between the remaining motor lead and the third line terminal measured."

In the last line of Table I, p. 850, of the September, 1913, issue, the word "Total" should be omitted.

PERSONALS

Mr. E. R. Treverton, of the illuminating engineering department of the Westinghouse Lamp Company, has severed his connection with that company, and is now with the Lighting Engineering Service Company at 50 Church street, New York City.

Mr. H. A. Greene, for a number of years advertising manager of the Bridgeport Brass Company, has recently been transferred to the New York sales office.

Mr. T. Duhan, formerly of the Salt Lake City district office of the Westinghouse Electric & Mfg. Company, has been made manager of the Montana Electric Company, of Butte, Mont.

Mr. W. W. Freeman, past president of the National Electric Light Association, has resigned as vice president of the Alabama Power Company, to accept the position of vice president and general manager of the Union Gas & Electric Company of Cincinnati, Ohio.

Mr. Verne W. Shear, until recently electrical engineer of the Northern Ohio Traction & Light Company, at Akron Ohio, is now established as commercial engineer and manufacturer's agent, representing the Condit Electrical Mfg. Company, Pittsburgh Transformer Company, and other well known manufacturers with offices at the Flatiron Bldg., Akron. Mr. Shear is a graduate of Case School, a member of the A. I. E. E., and was for five years commercial engineer with the Westinghouse Electric & Mfg. Company at East Pittsburgh.

Mr. T. C. Martin, secretary of the National Electric Light Association, is on a vacation trip abroad, sailing on the *Lusitania*. He will visit two or three capitals to study the central station industry and dispose personally of the many inquiries that have arisen in regard to the new class of foreign company membership in the Association.

At the convention of the American Electric Railway Association, at Atlantic City, October 13-17, the following officers of the American Association were elected: President, Chas. H. Black, vice president and general manager of the United Railroads of San Francisco; first vice president, C. Loomis Allen, vice president Syracuse Rapid Transit Company; second vice president, Chas. L. Henry, president and general manager, Indianapolis and Cincinnati Traction Company; third vice president, John A. Beeler, vice president and general manager, the Denver City Tramway Company; fourth vice president, L. S. Storrs, vice president, the Connecticut Company, New Haven, Conn. The following officers of the Engineering Association were elected: President, J. H. Hanna, chief engineer, Capital Traction Company, Washington, D. C.; first vice president, L. P. Crecelius, superintendent of power and electrical engineer, the Cleveland Railway Company, Cleveland, Ohio; second vice president, John Lindoll, Boston, Mass.; third vice president, B. F. Wood, mechanical engineer, Pennsylvania Railroad, Altoona, Pa.

NEW BOOKS

"Electrical and Mechanical Calculations"—A. A. Atkinson. 310 pages, 44 illustrations. Published by the D. Van Nostrand Co. Price, $1.50.

This volume is an educational textbook using only the simplest mathematics. In the main it is based on the experience of the author as Professor of Physics and Electrical Engineering in Ohio University. It is made up largely of a step-by-step arrangement of problems with explanations interspersed. In the present fourth edition, a number of revisions have been made. For instance the introduction of tungsten lamps has made necessary the insertion of new constants for use in calculating wiring. The principal headings after the usual explanation of fundamentals, are wiring for light and power, batteries, magnatism, e.m.f. of dynamos and motors, elements of dynamo design and alternating and direct-current distribution.

"Accident Prevention"—111 pages, 89 illustrations. Published by the United Traction Improvement Company of Philadelphia.

The above company has published in convenient book form, an amplified revision of the illustrated talk on accident prevention in certain public utilities, presented at the public policy meeting of the 36th Annual Convention of the National Electric Light Association last June. This book is prepared especially for superintendents, foremen, etc. It is essentially a picture book with a story explaining each photograph showing the wrong arrangement and the remedy.

NEW BOOKS.

"Principles of Irrigation Engineering"—F. H. Newell and D. W. Murphy. 286 pages, 54 illustrations, 14 plates. Published by the McGraw-Hill Book Company. Price, $3.00.

This subject has received increased attention for a number of years and a specific treatment embracing the important elements of irrigation work is of timely interest. This treatise being sponsored by government engineers of national reputation, is therefore, of authentic value. Both government and private enterprises have developed a large number of irrigation projects, which are already showing a profitable operation or indicating very clearly that the investment will in time bear due return. While apparently elementary, irrigation presents many phases and problems and the book has been designed to present the most prominent principles and conditions of irrigation developments. For this purpose, a broad survey of this branch of engineering is made, beginning with the historic introduction followed by the conditions of irrigation, irrigable lands, the water supply and features of construction applying to canals, distributing systems, pumping, drainage, storage, reservoirs, dams, and water rights, finally concluding with a chapter on economic considerations. Transmission of electrical energy for irrigation purpose has been given appreciable impetus and its application will be notably extended in the immediate future.

E.D.D.

"The Theory of Measurements"—A. de Forest Palmer. 248 pages, 16 illustrations, 23 mathematical tables. Published by the McGraw-Hill Book Co. Price, $2.50.

Exact measurements of physical quantities being impossible, it is of the greatest importance, in physical determinations, to know the degree of precision which is possible, as well as to estimate the probable error, and from a series of observations to arrive at a degree of precision greater than is secured by any single observation. Usually a series of measurements serves only to determine the probable limits within which the exact value lies. Errors due to known causes, such as unavoidable imperfections in instruments, may frequently be eliminated to a large extent by suitable computations. Others, however, are purely accidental in nature and arbitrary in magnitude; but their probable distribution, in regard to magnitude and frequency of occurrence, can usually be determined by statistical methods when a sufficient number of independent measurements are available. Professor Palmer's present work provides a complete classification of errors of measurement, together with a comprehensive mathematical treatment of the various methods of determining the probable extent and direction of error under various possible conditions. It is intended for mature students of physics and engineering, who have a thorough working knowledge of the fundamental principles of their respective branches, as well as of differential and integral calculus, and is based on the author's experience and lecture work, extending over a number of years at Brown University. The scope of the book is indicated by the list of chapter headings: General Principles, Measurements, Classification of Errors, The Law of Accidental Errors, Characteristic Errors, Measurements of Unequal Precision, The Method of Least Squares, Propogation of Errors, Errors of Adjusted Measurements, Discussion of Completed Observations, Discussion of Proposed Measurements, Best Magnitudes for Components, Research. The first seven chapters deal with the general principles that underlie all measurements, with the nature and distribution of the errors to which they are subject, and with the methods by which the most probable result is derived from a series of discordant measurements. The next five chapters are devoted to a more general discussion of the precision of measurements, based on the principles established in the preceding chapters. The applications of the theory of errors to the determination of suitable methods for the execution of proposed measurements are discussed at some length and are illustrated. Throughout the work, the importance of a careful estimate of the precision of the observations made in engineering work is emphasized. In the last chapter the relation between measurement and research is pointed out and the general methods of physical research are outlined. Graphical methods of reduction and representation are explained, and some applications of the methods of least squares are developed. The importance of timely and adequate, but not premature, publication of the results of investigations, in lucid and concise language, is emphasized, and some suggestions relative to the form of such reports are given. The mathematical tables at the end of the volume are exceptionally valuable. C. R. R.

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THE

ELECTRIC JOURNAL

Vol. X DECEMBER, 1913 No. 12

Ten Years of the Journal

The present issue completes the tenth volume of the JOURNAL. Starting as a means of disseminating technical information among a group of young engineers, it was soon found that there was a wide demand for a magazine designed especially for those aiming to fit themselves for effective engineering work. The first announcement and subsequent sending out for inspection of the initial issues resulted in the rapid development of a large subscription list. The articles were of a type not available elsewhere and it soon became evident that the JOURNAL was to become an important factor in the development of young engineers and in advancing the best interests of the engineering profession. While essentially a magazine for the young engineer, there were few who were too old to profit by keeping in touch with the JOURNAL. Its scope has been broadened to include a larger range of subjects. A great majority of the articles published have been of permanent value and are kept for future reference. It is thus especially necessary to avoid repetition of similar discussions and to be seeking out continually those new subjects which seem most worthy of special attention.

The location and associations of the JOURNAL in one of the greatest engineering centers of the world have made it possible to present the latest engineering practice as seen by those who are leaders in the profession. Very few contributors are professional writers—engineering is their profession—and each of them is an expert along some particular line. No particular claims have been made for literary style; it has been the aim rather to select for discussion those developments which seem most worthy of recording and to present the important facts in simple, concise language for the convenience of the busy man. The authoritative character of JOURNAL articles has had a great deal to do with its phenomenal growth.

Since the JOURNAL was started there have been many important engineering developments. The improvements in the lighting field have been especially notable. The use of electric power in various forms has increased by leaps and bounds. The central station industry had a gross income of about $100 000 000 in 1903, while the figure for 1913 will doubtless be considerably over $400 000 000. The distances over which power can be transmitted economically have been largely increased. In the railway field there have been numerous important developments; such as the use of higher trolley voltages with corresponding increases in efficiencies, the design and construction of improved cars and locomotives, and the general increase in the reliability of equipment. Another of the rapidly growing industries has been the automobile business, in which the past decade has seen an increase in production from 1 000 cars in 1903 to some 500 000 in 1913. While the progress in the past ten years has been very rapid, the indications are that the coming decade will witness an even more substantial growth. Power and transmission apparatus is now much more sturdy than it was ten years ago, and the idea of the relability of electric power is becoming almost universal. In this industry which is growing so rapidly it will be of greater importance in the future for those who are interested to keep in touch with the current engineering progress.

After having published over nine thousand pages, the JOURNAL is naturally in a much better position to serve its readers. Ten years ago it was merely an idea, today it is recognized as an important medium for promoting electrical progress. With the accumulated experience gained in the production of the first ten volumes as a basis, it is the purpose of the JOURNAL for the future to keep its readers in close touch with current progress and, through the coöperation of subscribers in indicating their needs, to present a continuous review of the best and latest practice as seen by those who are in daily touch with various lines of engineering activity.

Power-Factor Control by Rotary Converters

The effect of power-factor on the costs of operating power systems has been so frequently called to the attention of operators that engineers charged with the responsibility of operating generating systems have come to be perhaps a little over-zealous in their efforts to maintain high power-factors on the systems. An ideal condition would be to maintain unity power-factor throughout a system at all times, but this is obviously impracticable where mixed loads of power and lighting are served, and the problem then becomes one of balancing the losses attendant upon low power-factor against the expense of maintaining the system at high power-factor. This gives the operating engineer a splendid opportunity for exercising good judgment.

The synchronous motor, commonly utilized as part of a motor-generator set, has come to be accepted as an excellent agent for improving the power-factor of systems. There is no question about the ability of the synchronous motor, when properly applied, to accomplish this purpose, but the synchronous motor will not inherently deliver the expected results unless backed up by a fair degree of intelligent control on the part of the attendants immediaately in charge.

Mr. Stahl's article, in this issue, comparing power-factor effects of synchronous motors and rotary converters, very clearly illustrates this point. The presentation of this question as given by Mr. Stahl approaches the subject from a different angle than has heretofore been attempted. There is no argument as to the ability of the synchronous motor when properly operated to maintain either a constant voltage at the receiving end of the line or to maintain constant power-factor on a system within the limits of the motor, provided the motor is operated in such a manner as to accomplish the desired results, but simply putting a synchronous motor on a system and then turning it over to the care of the average station operator will, in most cases, give results that fall far short of expectations, especially with regard to corrective effects. The curves given indicate the necessity for careful attendance and show that the field strength must be varied with changing conditions of load, if expected results are to follow.

The rotary converter, on the other hand, while not inherently designed for power-factor correction, is shown to be an excellent medium for the automatic maintenance of constant power-factor, and the article goes further in demonstrating that, in cases where a wide variation in load occurs, the best average condition is obtained through the use of a rotary converter rather than through a motor-generator set as ordinarily manipulated.

Any power user who can maintain his average power-factor at approximately unity will naturally be favorably considered by a power company since the resultant effect of the application of a large load at unity power-factor to the average system will necessarily increase the power-factor on that system and, as a general proposition, a power customer cannot justly be called upon to operate his load at heavy leading power-factors for the purpose of correcting the power-factor of the general system, unless he is compensated in some measure for such service.

An interesting example of the results of rotary converter operation is found in the case of a large urban railway which purchases power from the central station serving the same community. Rotary converters were adopted as a transforming medium and the railway company was to be penalized in their rate if their average power-factor was maintained at less than unity. The first three months operation under this contract showed an average power-factor in excess of 99.75 percent, thereby demonstrating that rotary converters could be so operated as to maintain automatically a power-factor practically at unity. E. P. Dillon

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Simplicity in Automobile Wiring

When electricity was first applied to the transmission of intelligence by means of the telegraph a simple system for the wiring was used, one wire carrying the current from the battery through the key or switch to the relay at the other end of the line and through to ground which formed the return path. This was and still is the easiest and cheapest way of transmitting a small volume of current from one point to another. Later the telephone was arranged in the same manner, but the loop formed by several outgoing wires and the ground return wire were so wide that mutual induction and cross-talk was introduced. Then street railway systems came and their grounded circuits introduced so much noise in the telephone circuits that the latter were finally forced to use a two-wire system. Street railways continue to use the single wire, ground return system because it is the easiest, simplest and least expensive system, although occasionally they are unwillingly forced to a two-wire system, when excessive electrolytic effects on water and gas pipes have made the substitution necessary. With electric light and power systems a return wire was necessary from the first on account of the difficulty in getting good low resistance ground connections for the return path. It is safe to say that were it not for troubles due to self or mutual induction, electrolysis or the ground resistance, almost all electric circuits would use the simple grounded system.

In the article by Mr. C. E. Wilson on "Electrical Equipment for Automobiles," in this issue, an electric power and lighting system is shown which, on account of being a self-contained unit mounted on the metal frame of an automobile, makes possible the use of the simple single wire system. The metal frame of the car is admirably suited for the ground connection. No inductive effects have to be avoided, no electrolysis has to be considered and the conductivity of the frame is much higher than that of the wires of the ungrounded side of the circuit. No special precautions need be taken about joints in the frame as all bolts and screws must be set up so tightly for mechanical reasons that the electrical conductivity of the joints is very high. Such a system is inherently simpler than the two-wire system. There are only half as many electrical connections to make and there is twice as much room for making them. Insulation is simplified and much better insulation can be obtained for the same space used. In up-to-date installations, the wires are run in flexible metal conduit and with the single wire system only half as many wires are pulled through the conduit, and consequently smaller conduit can be used.

In general on any piece of apparatus which is made up in large quantities, and Mr. Wilson's figures show the immense quantities in which automobile equipment is demanded, it is desirable to break away from accepted standards and adopt new ones if by so doing simplicity is introduced. A few of the first automobile lighting systems used the two-wire system—copying after house lighting systems—but now that it is realized that there is no excuse for the two wires, automobile manufacturers are establishing as standard the simpler, more reliable single wire system. The time to standarize is now, before the number of installations has grown to the million mark and the difficulty of making any changes is increased.

A. W. Copley

Resuscitation From Electrical Shocks

In an article on "Artificial Resuscitation" in the present issue of the Journal, Dr. Chas. A. Lauffer makes some strong statements regarding the moral liability of a by-stander in case of failure to be able to practice artificial respiration upon the victim of an electrical shock or asphyxiation. The case is, however, even stronger. In addition to his moral obligation to others, from a purely personal and selfish standpoint, every electrical worker should insist that his co-workers fit themselves to perform the same good services upon himself in case of emergency. A combination of the two attitudes should speedily bring about a wide spread dissemination of information concerning the best methods of resuscitation from accidental suspension of respiration.

In this connection we desire to commend Dr. Lauffer's suggestion, made to the Eastern New York Section of the National Electric Light Association and heartily sanctioned by that section, that a suitable honorary medal awarded be to persons resuscitating victims of electric shock. The award to the person rendering first assistance should not, of course, be invalidated by the fact that the actual return to consciousness on the part of the patient may have occurred, after an interval of time, under the ministrations of a physician, or as the result of the application of some mechanical apparatus for artificial respiration, for in the majority of cases the services of the physician or the apparatus are liable to prove unavailing unless the respiration has been constantly maintained from the moment of the accident.

It is not intended by this statement to minimize in any way the importance of summoning a physician immediately, who by methods impracticable to the layman, may do much to stimulate the patient's heart action and nerve centers. But the physician is seldom near in time of accident. Even Dr. Lauffer himself, who has taught methods of resuscitation to others for years, and has been daily on duty close at hand to a large force of workmen, has never had an opportunity to practice the method he advocates upon the victim of electric shock, although a number of such cases have been successfully handled during the past year, by workmen whom he has trained.

We do not understand that the idea in the presentation of medals is to promote heroism. We have sufficient confidence in the inherent nobility of mankind to believe that every person will do all that he can to assist a fellow workman in time of emergency. But we do believe that the presentation of such medals will do much to encourage every person in any way connected with the electrical industry, to become familiar with the various methods of resuscitation, and to be prepared to act intelligently and promptly when the emergency arises. Moreover, as suggested in the paper such a method of recognizing cases of resuscitation will make possible the accumulation of a large amount of data, which will do much toward clearing up certain mooted questions regarding the relative efficacy of the various methods in vogue. From the scientific standpoint, such a system of records, showing for each case the voltage and conditions surrounding the accident, the nature of shock and burns, the method of disconnecting from the circuit, the subsequent treatment and the ultimate result, should prove of incalculable value.

Chas. R. Riker

One Thousand Questions and Answers

One thousand answers to questions have been published in The Journal Question Box. This service to our subscribers, which was started in a very modest way several years ago, has grown to be of considerable importance. Even before the regular publication of answers was begun, assistance had been rendered to numerous subscribers who were having difficulties. Many of these inquiries were of general interest, and it was thought advisable to publish selected answers so that our readers in general might receive the benefit of these suggestions. With the increasing number of these inquiries, it became necessary to arrange a regular system for handling them, and hence the inauguration of the Question Box. Many questions are of personal rather than general interest, and hence the answers are not published. All answers are forwarded to the inquirer direct as soon as prepared without awaiting publication, as many questions are quite urgent.

The Journal is peculiarly well fitted to furnish authoritative answers on a great variety of engineering topics. It does not depend on a single group of individuals for replies, but refers each question to an expert in the particular subject involved, who is best fitted to furnish an authoritative answer. With such a large staff of expert advisers at hand, the Question Box editor is able to carry on a very high grade type of consulting work, and many of our readers have found the Question Box worth many times the price of a subscription.

Since the Question Box was started a number of other question boxes have been begun along similar lines, which are undoubtedly of great assistance to those so served, notably the question boxes provided for members of the National Electric Light Association and the American Electric Railway Association. Excellent as these are, however, there is one feature which, while probably a necessity in these two instances, is not productive of assurance on the part of inquirers, and that is the giving of answers from a number of different persons which may or may not agree in their essentials. It has been the aim of the JOURNAL, whenever any doubt or difference of opinion was present, to consult other authorities and revise the answers in various ways until a composite reply is secured, which is the best answer obtainable from a number of those who are most expert in the subject. Each question is passed upon by at least three persons and, whenever advisable, by others before being published in the JOURNAL. It is worthy of note in this connection that those inquirers who are farthest removed from the large centers seem to be most appreciative of service such as the JOURNAL has been offering. In many cases, the inquirers have encountered difficulties in operating work which they are expected to remedy and a prompt, direct reply, giving the best solution of their particular problem, is naturally appreciated.

After publishing the answers to a thousand questions, the editors of the JOURNAL would like an answer to a question which has been suggested a number of times. The question is, Are a sufficient number of readers interested to make it worth while to review all of the answers published to date and classify them in topical form, grouping all answers on any one subject together, and publish them in book form at a moderate price. At present the replies are scattered through several volumes, and it is becoming increasingly difficult to locate quickly all answers which have appeared on a given subject. It now remains to be determined whether the demand is large or small. If there is a considerable call for such a publication it will be undertaken, with the idea of making it a permanent feature, by revising the publication from time to time to include new answers which have appeared since the last edition was published. There is no doubt that the Question Box contains a great deal of valuable information. If JOURNAL subscribers are sufficiently interested, the editors will undertake to get out a Question and Answer book for their use. What say you?

PROTECTION AGAINST SHORT-CIRCUITS*

P. M. LINCOLN

THE large and rapid increase in the size of electric plants during recent years has brought about many new problems, not the least of which is the constantly increasing difficulty of obtaining adequate protection from short-circuits. This paper proposes to deal with the general subject of protection against short-circuits, tracing the development of the various measures that have been used, and proposing certain modifications of existing pratices that seem to the writer to be logical.

Circuit protection may be regarded from two viewpoints, namely:—1—Protection to apparatus; 2—Protection to service. To the operating man, protection to service is paramount. He aims at all cost, to keep power on his lines continuously; if need be, he is willing to sacrifice protection to apparatus to a considerable extent to attain this end. In other words, whenever protection to service and protection to apparatus happen to conflict, the operating man will choose protection to service rather than to apparatus.

Simultaneous with the growth of electric supply stations, at least two new effects began to be noticed at the time of short-circuit. These effects were:—

1—Severe mechanical stresses along the path of the short-circuit, becoming particularly damaging in the distortion of generator armature windings.

2—The inability of the then existing types of oil circuit breakers to open short-circuits on large plants successfully.

It was on the first Niagara generators that armature winding distortions were first noted. The writer well remembers making a considerable number of short-circuit tests upon the original Niagara plant, for the purpose of testing switches, etc. Shortly after that it was observed that the armature conductors of the generators, at the point where they projected from the iron of the armature, were bent, the bending being particularly noticeable at the division point between adjacent phases. It was not difficult to establish a connection between the short-circuit tests and the condition of the armature windings. In the case of the Niagara generators the remedy consisted in the design and use of a special form of blocking for bracing the armature conductors, which is believed to be the first attempt, on any machines, to guard against distortion of armature windings due to excessive short-circuit currents.

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*A paper read at the annual convention of the Association of Edison Illuminating Companies, Cooperstown, New York, September 9-11, 1913. Reprinted by permission.

At Niagara the generator windings were not the only part of the path of short-circuit current in which mechanical stresses were observed. Bending of bus-bars, and the throwing of cables off cable racks, were also experienced at times. In one case a short-circuit at a sub-station about one-half mile from the main generating station resulted in throwing about 2 000 feet of 1 000 000 circ. mil lead-covered cable from its bracket on one side of a narrow tunnel to a lower bracket on the opposite side. This experience, coupled with some others of a similar nature, lead to clamping down the cables thereafter.

Although the Niagara plant was the first to experience trouble with the distortion of armature windings, it was, by no means, the last. One of the elements that governs the amount of mechanical stress set up in armature windings is the normal capacity per pole of the generator. With the advent of turbo-generators came much higher speeds, therefore, fewer poles, as well as a marked increase in generator capacities. The problem of winding stresses, therefore, has reached a maximum with the coming of the large capacity, high-speed, modern turbo-generator.

During the same period that this problem of armature winding distortion was developing another serious problem also began to confront the electrical engineer. It was noticed that the breaking capacity of the then existing oil switches was not sufficient to take care of the largest of the central stations of the day, and it began to be realized that when stations containing more than a given aggregate capacity were short-circuited, no oil switch that existed, up to that time, could be relied upon to open successfully. Analysis, as well as experiment, showed that during the first few cycles of a short-circuit the amount of current that may be taken from a generator, or other synchronous machine, is vastly in excess of the value to which it settles after a few seconds. It is the existence of this enormous first rush of current that gives rise to both of these difficulties. As soon as this phase of the problem was thoroughly appreciated, the natural remedy that suggested itself was to employ some means of cutting down this first rush of current; and thus we were logically led to the use of choke coils in generator leads. Although the use of such choke coils is less than five years old, they are now considered, by many engineers, as the standard arrangement when designing plants of relatively large capacity.

The questions which now arise, and which are discussed in the following pages are:—

1—Is this obvious remedy, which was first applied, the best one?

2—Is it not possible to arrange current-limiting devices at places other than in generator circuits and obtain better results?

A single line diagram of an elementary arrangement of generators and feeders is shown in Fig. 1. In general, in the large centers, power is distributed through underground circuits. A plant which distributes its power underground will, normally, have many more feeders than there are generators. This follows from the simple proposition that the amount of energy which it is possible to take out in a single feeder underground is limited by the matter of maximum cable capacity and the size of standard ducts. A 250 000 circ. mil three-conductor cable has an over-all diameter of something over three inches, and is, therefore, about as large as can be drawn through standard city conduits. The limit in continuous carrying capacity of cables of this size does not exceed 3 000 k.v.a. at distributing voltages of 11 000 and less, a voltage that few underground distributing systems exceed. It is rarely possible to install feeders so that they are used to their maximum capacity, and, therefore, the average size of underground feeders may safely be assumed at considerably less than 3 000 k.v.a. On the other hand, the generators used in modern central stations are rarely less than 10 000 k.v.a each, at least not in those central stations which have attained sufficient size to give rise to the problems which have been mentioned It is evident, therefore, that the number of feeders which will radiate from a modern central station will be considerably in excess of the number of generators which that station utilizes, ranging from possibly three times as many as a minimum to 15 or 20 times as many as a maximum.

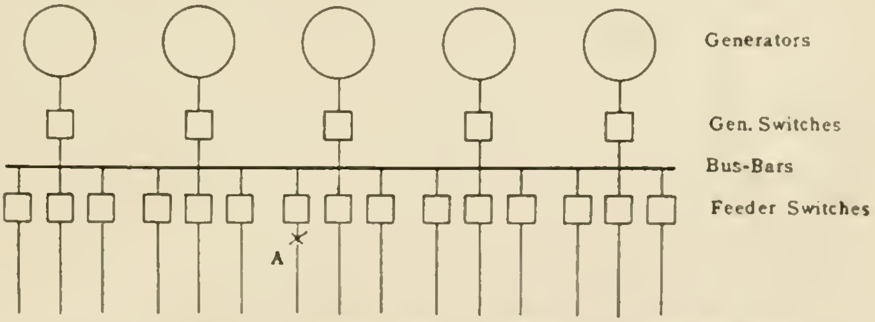

FIG. 1—TYPICAL SINGLE-LINE DIAGRAM OF STATION WITHOUT CHOKE COILS

A power plant arrangement such as was standard before the era of choke coils is indicated in Fig. 1. Let us assume a short-circuit on this system, for instance, on a feeder at a point close to the bus-bars, as at *A,* and let us analyze the effects of such a short-circuit. Of course, an enormous current will flow through this short-circuit, being a maximum during the first cycle. During the first few cycles practically the only impediment offered to the passage of current is the inherent reactance of the generator windings themselves. The voltage that will be taken up in the arc at the point of the short-circuit may possibly have a value as high as a few hundred volts at the utmost, and it is obvious that this will be but a very small proportion of the total voltage that existed just before the short-circuit occurred. The remainder of the bus-bar voltage must be accounted for in other ways. Some of it, of course, appears in the resistance and reactance of the bus-bars themselves, and of the generator leads up to the point of short-circuit. The amount of resistance and reactance between the generator terminals and the point of short-circuit is, however, very small compared to the inherent reactance and resistance of the generator windings themselves, and it is obvious, therefore, that by far the largest part of the voltage of the bus-bars will be taken up in overcoming this generator impedance. Also, since the generator reactance is many times as great as its resistance, it is evident that most of the voltage will be taken up in overcoming inherent generator reactance. Since practically all of the voltage is thus used up inside of the generators, the amount left on the bus-bars will be a relatively small proportion of normal. The condition of a short-circuit at *A* will, therefore, give rise to excessive currents through the generators, the value being limited only by the design of the generator as regards inherent reactance. On many of the earlier types of machines such excessive currents caused distortion of the windings.

The current through the feeder switch on feeder *A* will be still more excessive, since the current from all of the generators will pass through this switch. Nor is this all of the shock that will be sustained by the switch; not only do the generators feed current into such a short-circuit, but every synchronous machine on the entire system does the same. The effect of distant synchronous machines will be limited, owing to the fact that they will probably have a certain amount of feeder cable between them and the point of short-circuit, but their effect is such as to increase the strain on the switch over what it would be if the load did not consist of synchronous apparatus. The shock on the feeder switch will, therefore, be tremondously severe. The shock on the generator switches, if they are automatic, will also be severe, since each generator switch will momentarily deliver all of the current that it is possible to obtain from the generator, and, if the generator circuit breaker is ever to trip, it will trip under such conditions. It is obvious, however, that the shock on the generator circuit breakers cannot be as severe as that upon the feeder circuit breaker, since the latter must pass the current from all synchronous apparatus, whereas the generator circuit breaker is limited to the maximum possible output of a single machine.

The two effects that will be most noticeable, from a short-circuit such as assumed, are the distortion of generator windings and the failure of the feeder switch. There is another effect, however, that, from the standpoint of protection to service, is still more important, and that is the dropping out of step of synchronous apparatus during the interval that the short-circuit at *A* persists. Since practically all of the voltage of the bus-bars is taken up in circulating current through the generator windings, the proportion that remains on the bus-bars during the persistance of the short-circuit is very small. This means, of course, that no current can circulate between synchronous machines during the short-circuit interval, and they are, therefore, free to drift apart during this interval, as conditions thereon may dictate. Assuming, for instance, that we have a synchronous motor carrying full load, and that a short-circuit such as we have assumed occurs, the motor will begin to slow down rapidly, due, not only to the drag of its load, but also owing to the energy which the motor itself begins to pump into the short-circuit. The generators themselves may also begin to slow down, owing to the fact that they are pumping energy into the short-circuit. The rate of slowing down of the various synchronous machines will not be the same, since it will depend upon the amount of drag, as well as upon the momentum of the revolving parts. Therefore, if the short-circuit persists more than a very brief length of time the voltage, when it reappears, will find another short-circuit, owing to the fact that the synchronous apparatus of the system is in improper phase relation. If the amount of synchronous apparatus on the system is relatively small it may be dragged back into step within a few seconds. However, in order to drag synchronous apparatus into step with a generator, the amount of current taken is excessive, so excessive, in fact, that it is impossible for the generators to supply sufficient current for this purpose, if all of the load on the generators consists of synchronous apparatus. While a generator might drag back a quarter of its capacity of synchronous apparatus into step, it will be impossible to accomplish this result when the synchronous load amounts to 100 percent or more of the generator capacity, such as it is in stations having rotary converters or motor-generator sets as their principal load.

Just what length of time is required for the dropping out of step of synchronous apparatus is difficult, if not impossible, to say. Certain tests made with synchronous apparatus on the 25-cycle Niagara system have indicated that a suspension of voltage for three cycles would not cause a pulling out of step, while if suspension persisted for eight to ten cycles, a falling out was probable. This is simply one case, and that other cases would be similar does not follow. The nature of the apparatus evidently has an important bearing on this point. Synchronous motor-generator sets, for instance, will evidently be much more liable to fall out of step during suspension of voltage than will rotary converters, because the load on a synchronous motor-generator set will cause a mechanical drag, while the cessation of continuous voltage, simultaneously with the cessation of alternating voltage in the case of a rotary converter, will also suspend the drag of the load.

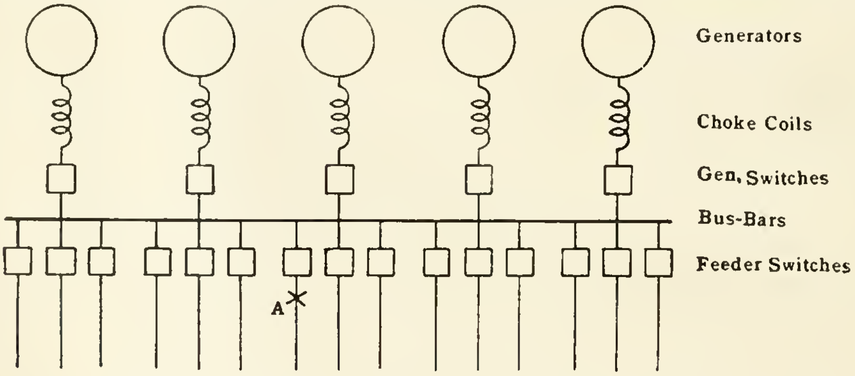

FIG. 2—CHOKE COILS IN GENERATOR CIRCUITS

In applying a remedy for the difficulties that were thus manifested during short-circuits, it was the obvious damage to windings and switches that centered attention, and the remedy was aimed directly at these difficulties. The next step in the matter of circuit protection was the installation of choke coils in generator leads.

Let us analyze, as we have in the case of Fig. 1, the effect that the presence of these choke coils will have in the case of a short-circuit at point *A* in Fig. 2.

1—It is evident that the rush of current through the generators will be reduced, owing to the fact that the current is now limited by external, as well as the internal reactance of the generator windings. Bearing in mind that the stresses in the windings vary as the square of the current therein, it is evident that the problem of winding distortion is well met by this remedy.

2—The amount of current through the switch is reduced, since the current from the generators has been decreased. It should be pointed out, however, that it is only that portion of the current that comes from the generators that is reduced by this remedy, and that that part of the current that comes from the synchronous apparatus, other than the generators, is not affected by this addition of generator choke coils. It is evident, however, that the presence of these choke coils in the generator leads will considerably reduce the strain upon the circuit breaker in the feeder circuit, as well as upon those in the generator circuits. Whether or not the easing up is sufficient to allow the circuit breaker to act properly is entirely a question of degree, and depends upon the conditions surrounding the case. If a 50 000 k.v.a. plant is large enough to cause a circuit breaker to blow up without the use of generator choke coils, a 100 000 k.v.a. plant will cause an equal amount of distress, even when the choke coils have been added; assuming that the external choke coil has a reactance no greater than the internal reactance of the generator winding—an assumption which is usually not far from correct. Although the remedy, therefore, is in the right direction for easing up on circuit breaker stresses, the question of degree is always present, and each case must determine for itself whether or not the circuit breakers installed are capable of taking care of the service. In any event, any feeder switch in Fig. 2 is in position to receive the maximum possible stress that may be caused by this system, and all of the feeder circuit breakers should be capable of withstanding the maximum shock that the system is able to give.

3—The disappearance of voltage on the bus-bars during the persistance of a short-circuit is more complete with choke coils arranged as in Fig. 2, than if there are no choke coils. The tendency, therefore, for synchronous apparatus to stay in step is materially reduced by the use of such choke coils. It is the prevention of this dropping out of step of synchronous apparatus that is of the utmost importance from the viewpoint of continuity of service. Protection to generator windings and to switches constitutes more of a protection to apparatus than a protection to service, whereas the maintenance of voltage on the bus-bars during the persistance of a short-circuit constitutes a protection to service rather than to apparatus. Any measures, therefore, by which we can maintain voltage on the bus-bars during the continuance of a short-circuit will thereby tend to protect the service. The fact, therefore, that this use of choke coils makes synchronous apparatus all the more certain to drop out of step is one which constitutes a very decided disadvantage to placing choke coils in generator leads, as indicated in the arrangement shown in Fig. 2.

The arrangement of choke coils shown in Fig. 3 is such that it will improve conditions viewed by all three of the preceding standpoints. Here we remove the choke coils entirely from the generator leads and place them in the feeder leads. Also, instead of making these choke coils of the order of five to ten percent voltage at full load, as they usually are when placed in generator leads, we would propose to make them of the order of from three to six percent, or possibly less. Therefore, while the number of choke coils is considerably increased by the arrangement shown in Fig. 3, the aggregate k.v.a. capacity of choke coils is reduced. The cost of installing such choke coils should not be materially modified by this change in location.

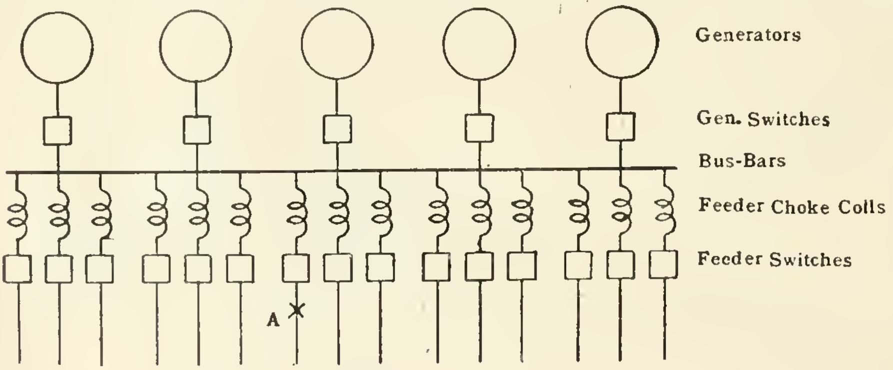

FIG. 3—CHOKE COILS IN FEEDER CIRCUITS

Let us see, now, what will happen when we have a short-circuit at the point *A* in Fig. 3.

1—The strains on the generator windings will be reduced to a value much lower than would exist with the arrangement in Fig. 2. This follows from the consideration that the capacity of a single generator is, as pointed out above, much greater than the capacity of a single feeder, and, consequently, the value of a three percent reactance in a feeder circuit of say 3 000 k.v.a. capacity will have as high a value as that of even a ten percent reactance on a generator capacity of say 10 000 k.v.a. Moreover, all of the current which passes through the feeder reactance must come from the generators, and this total current is divided into as many parts as there are generators operating. It is evident, therefore, that the generator currents are limited to a very much smaller amount by the arrangement shown in Fig. 3. I do not consider this of controlling importance, since, as will be brought out later, modern generators have been designed with a very much improved bracing of windings, so that they are perfectly capable of withstanding any short-circuit conditions that are apt to be imposed upon them, and do not need to have the protection of choke coils. The main reason for suggesting choke coils, as shown in Fig. 3, has no relation whatever to the elimination of distress in generator windings.

2—The stresses on the feeder switches are very much reduced by the arrangement in Fig. 3. Suppose we assumed, for instance, a 100 000 k.v.a. plant, equipped with generator reactances which will limit the generator current to, say, eight times full load; in case of a short-circuit close to the bus-bars the feeder switch on such a plant would pass a current equivalent to 800 000 k.v.a. at normal voltage. If, now, we assumed an arrangement similar to that shown in Fig. 3, and assume a feeder capacity of 3 000 k. v.a., with three percent reactance, we can see that the worst possible condition that the switch could get would be a current equivalent to 100 000 k.v.a. at normal voltage, or one-eighth of what it would have to stand with the arrangement as in Fig. 2. This assumes that the feeder reactance is the only impediment to the passage of current, and takes no cognizance of the inherent reactance of the generators, which evidently would make the difference in shock on the feeder circuit breaker larger than indicated in this comparison. It is evident, therefore, that with the arrangements as in Fig. 3, either the switches will have a much ampler margin of safety, or we may use a smaller and cheaper switch and still retain the same margin of safety over the arrangement shown in Fig. 2.

The voltage on the bus-bar with arrangement as in Fig. 3 will stay nearly to normal, and there is very little tendency for the synchronous apparatus of the system to drop out of step.

The arrangement of Fig. 3 provides choke coil protection only for those short-circuits which occur on the feeders beyond the point where the choke coils are inserted, and they do not give protection to short-circuits which occur on the bus-bars, or upon the generator leads themselves This objection is, however, largely offset by the fact that the probability of a short-circuit occurring upon feeder circuits is vastly greater than upon the conductors back of these feeders. For one thing, in the ordinary system, the amount of feeder circuit is somewhere around 100 to 1 000 times the aggregate length of the circuits back of the feeder choke coils. For another thing, it is possible to design a construction and installation of bus-bars and generator leads such as to reduce the possibility of a short-circuit thereon almost to the vanishing point. Bus-bars, for instance, are normally run in brick compartments, so as to make it almost impossible to obtain a short-circuit thereon. Generator leads may be run with single conductor lead-covered cables in such a manner that a short-circuit between them must be preceded by a ground to the lead sheathing, and a proper installation of grounding resistance may be made such as to eliminate such a ground before it can develop into a short-circuit. Many engineers, therefore, will be content with the protection which is offered by the use of feeder reactances, and will not deem it necessary to install protection against the very remote contingency of a short-circuit upon the bus-bars or generator circuits. However, it is entirely possible to secure a degree of protection against this contingency at least equal to that given by generator choke coils, and still retain the marked advantages of choke coils in the individual feeder circuits.

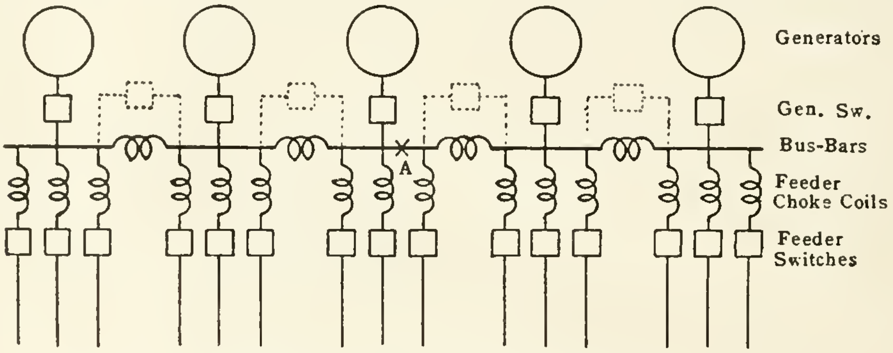

FIG. 4—CHOKE COILS IN FEEDER CIRCUITS AND SECTIONALIZING CHOKE COILS IN THE BUS-BARS

The method of securing such protection is shown in Fig. 4. Here we have an arrangement similar to that in Fig. 3, except that adjacent sections of the bus-bars are separated from each other by interposing choke coils. Preferably, the number of sections into which the bus-bars are divided by such choke coils should be equal to the number of generators, and the feeders should, likewise, be divided into the same number of groups of as nearly equal capacity as it is possible to arrange. A short-circuit on some section of the bus-bar, as at *A,* Fig. 4, will cause the voltage on Section 3 of the bus-bar to be reduced practically to zero and, in all probability, whatever synchronous apparatus is attached to the group of feeders on this section of the bus-bars will drop out of step. However, it is not so much the continuity of service on this group of feeders that we desire, as it is to secure continuity of service on the remaining groups. On the adjacent sections of bus-bar *2* and *4* the voltage will not fall to zero, because of the drop through the sectionalizing choke coils. These choke coils can be made of such a value that even with a short-circuit on one section of the bus-bars, the voltage will remain of such a value that synchronous apparatus on these adjacent sections will still be held in step.

An objection may be raised that when bus-sectionalizing choke coils are sufficiently large to give adequate protection to the sections adjacent to a short-circuit section, there will also be sufficient voltage drop through these choke coils from the normal current that may circulate between bus sections to cause an inadmissable difference of voltage between such adjacent sections. To meet this objection, we suggest short-circuiting said reactances with a quick acting oil circuit breaker, and an arrangement of switches as shown by the dotted lines in Fig. 4. It is quite possible to make the speed of such a circuit breaker high enough so that the current limiting function of the choke coil will come into action in less than 0.15 sconds, after a short-circuit has occurred, and, in general, this is not a sufficient length of time to cause synchronous apparatus to fall out of step. This scheme cannot, of course, prevent service from being interrupted upon the group of feeders connected to the short-circuited section of bus-bar, but it should be capable of preventing the interruption of service on all other groups. The sectionalizing switches should, of course, be set for such a current that they will not trip at a value smaller than the maximum that can be passed by a single feeder reactance. Thus the sectionalizing switches will not come into action for any condition except a short-circuit, either upon a bus-bar or upon generator leads; a contingency which, as pointed out before, is very remote.

The objection may be raised to the scheme shown in Fig. 4 that the generator feeding the short-circuited section of the bus-bar has no choke coil buffer to ease off the shock on the armature winding caused by the short-circuiting current, and further, that when the sectionalizing choke coils are short-circuited by switches, as shown in the dotted lines, a similar shock will be experienced by every generator on the system, since it is impossible for these sectionalizing switches to act soon enough to prevent such a shock upon the windings. The only answer to this objection is to admit, frankly, that in those cases where the generator windings are such that they cannot withstand the shock of a short-circuit, it is not safe to adopt any scheme of protection that does not provide for generator choke coils, and the arrangement shown in Fig. 4 should be supplemented by such choke coils. In such cases, the risk that a single, heavy short-circuit will put all of the armature windings of the plant out of commission at one time is too great a one for any plant to assume. If, therefore, the generators are such that they are not self-protective, it is wise, by all means, to use choke coils in the generator circuits. However, modern generators can be built, and are being built, so that they can, and do, withstand the shock of short-circuits without the assistance of choke coils in their leads. This is true even with the largest capacity, and the highest speed machines yet built, and is, of course, true with a larger margin of safety for smaller capacity and lower speed machines. Emphasis should be laid on the point that the generator choke coils do not accomplish the same ends as do feeder and bus sectionalizing choke coils, since, with generator choke coils only, it is impossible to prevent drop in voltage upon the bus-bars, and the consequent pulling out of step of all synchronous apparatus in case of a short-circuit on the main bus-bars. In brief, the function of the generator choke coils is to give protection to apparatus, while the function of the feeder and the bus sectionalizing choke coils is to afford protection to service.

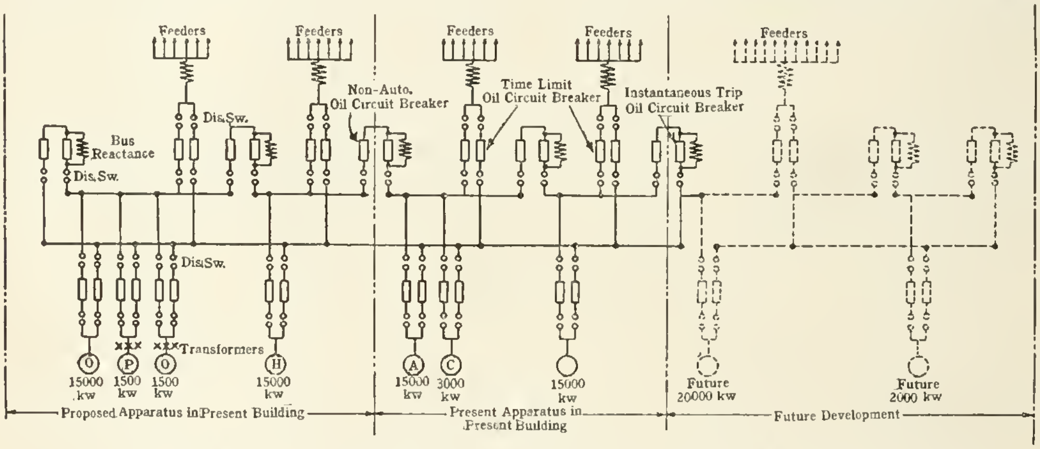

FIG. 5—SCHEMATIC DIAGRAM OF THE WIRING IN THE MAIN GENERATING STATION OF THE DUQUESNE LIGHT COMPANY, PITTSBURGH

The Duquesne Light Company, of Pittsburgh, recently decided to enlarge their main generating station, to such an extent as to make it practically a new plant. Something over 60 000 k.v.a. in generators is to be installed in the immediate future, and, eventually, the capacity is to be increased to over 100 000 k.v.a. After a careful consideration of all the features that enter the design of a logical system of protective choke coils, the engineers of this company, in collaboration with a prominent firm of consulting engineers in New York, decided on a station layout very similar to that shown in Fig. 4. The diagram of connection which is now being used in laying out the switching equipment for this plant is shown in Fig. 5. It will be noted that the only modifications over the scheme shown in Fig. 4 are that two busses are used, one of which is not provided with the sectionalizing choke coils, and, in addition to the choke coils and its shunting oil switch, there exists a second oil switch that can be used to cut apart entirely the adjacent sections of the main bus, a detail which is not indicated in Fig. 4. Naturally, also, both generator and feeder switches are installed in duplicate, so as to make it possible to take power either from the sectionalized bus or from the unsectionalized bus, as may be desired. This, we believe, is the last word in the protective equipment for large central stations.

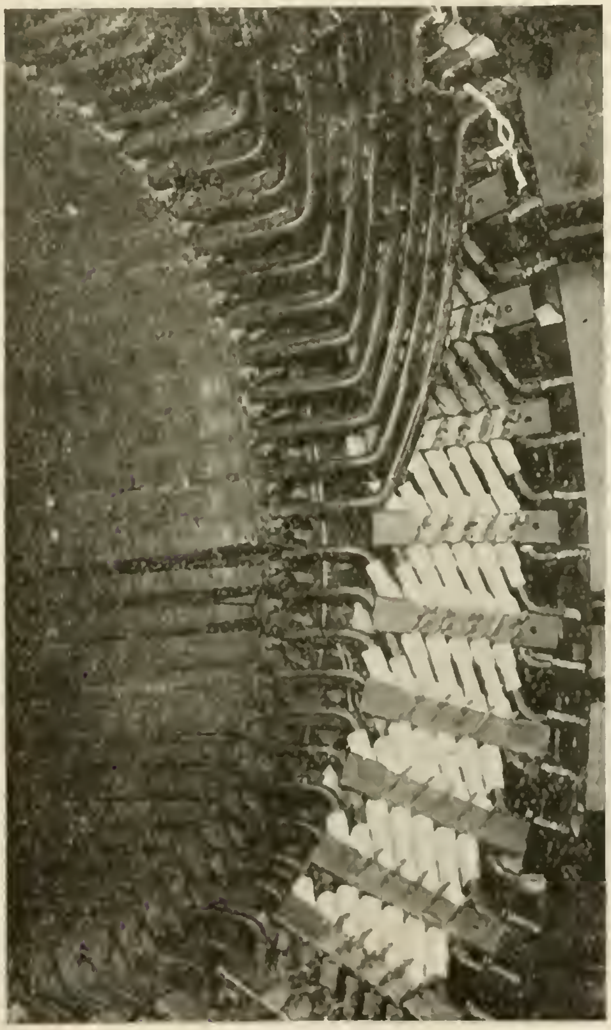

FIG. 6—DETAILS OF BRACING THE ENDS OF THE ARMATURE COILS OF A 20 000 K.V.A., SIXTY CYCLE TURBO-GENERATOR

Considerable reference has been made, in the foregoing, to the matter of ability of modern generator windings to withstand short-circuit conditions. This ability is the result of a long process of development in the design of bracings for generator windings. In the early days there was no inadequate conception of the enormous mechanical forces that were set up in armature windings by the very heavy currents that circulated on short-circuits. As the conception of the true magnitude of these strains began to be realized, the design of bracing methods improved. Fig. 6 shows the method of bracing used in a recent sixty cycle generator of approximately 20 000 k.v.a. capacity. This is typical of the bracings which are being used in modern generators. Fig. 7 shows a complete winding, and indicates how the braces are bolted directly to the brackets, resting, in turn, directly upon the armature frame. An inspection of Fig 6 shows the use of metallic spacers between the upper and lower layers of coils, which spacers are provided with projections, so as to hold each individual coil into its original and proper position. It is evident that this scheme of spacers will give a bracing of the end projection of these coils which is almost as firm as the portion of the coil which is embodied within the armature slots. With such a method of bracing, the generator winding is capable of withstanding any shock which may come to it on account of short-circuits, and it is not necessary to furnish further protection by the use of choke coils intended to keep down the amount of current on short-circuits. In other words, modern improvements in the methods of bracing armature windings enable us to eliminate entirely one of the main reasons that has led to the adoption of choke coils in generator leads.

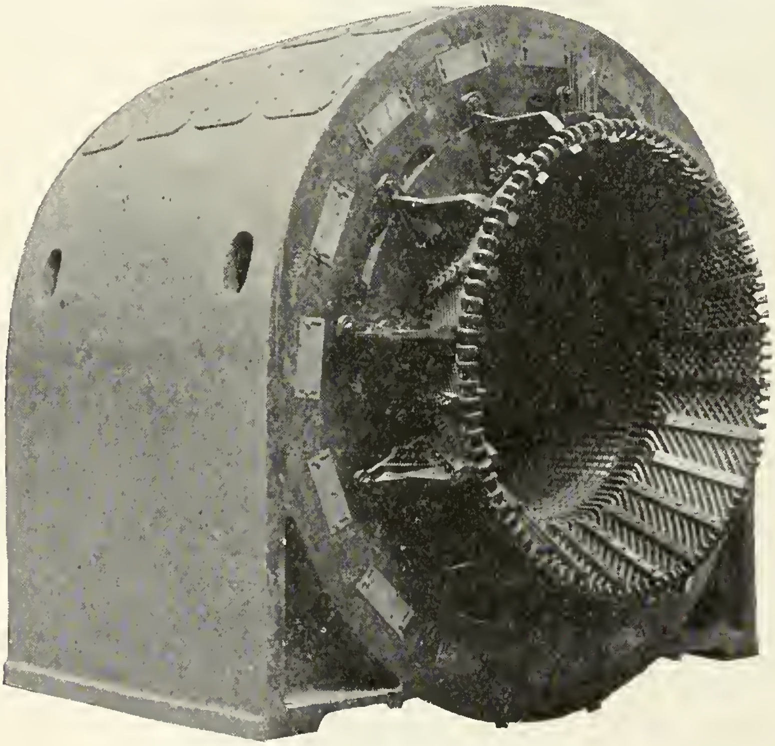

FIG. 7—COMPLETED WINDING, SHOWING BRACING

In the matter of the breaking capacity of oil switches, also, modern development has led us beyond the point that prompted the installation of choke coils for the purpose of easing the shock on such switches. It has been pretty well demonstrated that a circuit breaker, having a single break (unless it has impractical dimensions and cost), is not capable of opening short-circuits successfully in stations which exceed 50 000 to 75 000 kilowatts in installed capacity. When the installed capacity advances beyond this figure it has been found impossible to rely on any circuit breaker having but a single break in each pole. This difficulty has been met by the design of the so-called "reactance type" circuit breaker. In this type of circuit breaker we resort to the Napoleonic expedient of dividing the opposing forces into two or more sections, and then defeating them in detail. In other words, instead of trying to break the entire power in one break, the reactance type of circuit breaker has two breaks, the first being shunted by a suitable reactance, which reduces the current to such a point that the second break can then interrupt the circuit without difficulty. The two breaks are carried by the same mechanism, and the reactance forms a part of the circuit breaker itself.* This device of opening the circuit has gradually, for the present at least, put the circuit breaker in the lead in the race between the circuit breakers and the station capacity, and probably will enable the circuit breaker to stay ahead. The same idea can be extended indefinitely, if necessary, using a multiplicity of breaks, each break reducing the current to a point where the next succeeding break will not be overstrained. So far as we can judge at present, station capacities will have to exceed anything yet proposed before it will be necessary to resort to more than two breaks in order to secure successful operation.

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*For further information on this type of circuit breaker reference may be had to an article entitled "Recent Developments in Oil Circuit Breakers," by Mr. J. N. Mahoney, appearing in the August, 1913, issue of the JOURNAL.

SOME POWER-FACTOR EFFECTS OF RAILWAY MOTOR-GENERATORS AND ROTARY CONVERTERS

NICHOLAS STAHL

A central stations in supplying power to electric railroad and traction systems. At the same time, the central stations traction systems. At the same time, the central stations have become more discriminating in respect to the kinds of loads connected to their networks. The power-factors of the oncoming loads are being scrutinized, with the idea of insuring the central station against the ill effects of poor power-factor. Many power companies either refuse loads of known poor power-factor, or accept them with a rate penalization. Contracts for the sale of power to railroads frequently contain a provision, much like that in an existing contract between a prominent transmission system and a traction road in the South, reading as follows:—

> "The electrical energy to be furnished hereunder shall be in the form of 60 cycle, three-phase, alternating current at approximately 2 300 volts. Power company agrees to maintain the frequency and voltage within five and ten percent respectively.
>
> It is further understood that the synchronous transformer or converter apparatus shall be so constructed as to allow of adjustment to give a power-factor of unity when so desired, and throughout the periods of operation of said apparatus, traction company shall so adjust same as to maintain, as far as possible, power-factor at unity."

The obvious intent of this wording is to preclude the use, by the traction company, of generators driven by induction motors, which, in the present commercial state of the art, limits the converting apparatus to synchronous motor-generator sets or rotary converters. The wording used requires only that, with the reciprocal obligations fulfilled, the railway apparatus be capable of operating at all loads at unity power-factor; it does not exact—as would be most unreasonable—that the power-factor of the railway's receiving circuits be maintained constantly at unity. Aside from its unreasonableness, such a demand would work against the best interests of a power company which has long transmission lines, involving at the frequency used, a considerable charging current, which at times of light energy load at the power house requires the useless operation of considerable generator capacity at so low a leading power-factor that the addition of a considerable amount of lagging current would afford much relief.

For example, suppose the charging kilovolt-amperes to be 6 000; then with generators of 4 000 k.v.a. individual capacity installed, two machines would have to run continuously in order to keep the line at full potential. The energy loss due to this charging current, would, however, be very small, say 200 kw, so that the line would be operating at three or four percent leading power-factor. If a mill load of, say 1 500 kw, at 50 percent power-factor lagging could be added, the total demand on the generators would be reduced to 3 800 k.v.a. at 45 percent leading power-factor. Adding the mill load would thus permit the shutting down of one unit, which would, moreover, work at greater efficiency on both its steam and generator ends.

But mill loads occur usually only in the day time, while the charging current, like Tennyson's brook, "goes on forever." Resort might be had to choke coils, but this additional apparatus is unnecessary with synchronous motors driving the railway load, since the power-factor of synchronous apparatus is adjustable over a large range.

In discussions which appeared in the technical journals about a decade ago, concerning the relative merits of synchronous motor-generator sets and rotary converts, efficiency and first cost formed arguments in favor of the rotary converter, while ruggedness and voltage variation favored the motor-generator; as to voltage variation, the railways have well nigh universally adopted flat compounding, so that the two types of converting apparatus are on a par on that score.

Twenty-five cycle rotary converters long since became so standard for railway service that the sale of a motor-generator set for this frequency would be a matter of wonder. Sixty cycle rotary converters were formerly much less reliable than they are today. The last four or five years, with the newer designs, have wrought a great change in the viewpoint of those conversant with the actual operation of these machines, and even with the longest lines, and the higher voltages, the new 60 cycle converter is doing its part with that steady unobtrusiveness which always is a pleasure to the operating engineer.

With the demand, however, for machines capable of correcting a bad lagging power-factor, a new advantage has been urged for the synchronous motor-generator set, in that, for a slightly increased cost, the motor may be made suitable for operating at any reasonable leading power-factor, say 80 or 70 percent, so that it performs really two functions, that of carrying its rated energy load, and that of a "synchronous condenser" of 60 or 72 percent, of its normal rating. The rotary converter, as ordinarily designed, is inherently incapable of operating safely,* except for short periods, when carrying its normal rated direct-current load, at power-factors, either leading or lagging as low at 80 or 70 percent. Where, therefore, a great power-factor corrective capacity is essential, the synchronous motor-generator set has an advantage inherently impossible to the rotary converter as ordinarily designed and operated and the higher efficiency and other advantages of the converter may be outweighed.

It has further been urged that the synchronous motor may be so operated by a Tirrill regulator as to assist in the maintenance of constant alternating voltage at a sub-station, whereas the standard rotary converter may not safely be so operated. But it must not be forgotten that, from the standpoint of the railway, this means buying the Tirrill regulator and a larger, special exciter, for no good to the railway company, but merely to help the transmission company; and also the operators must be capable of caring for Tirrill regulators, and must see to it that the regulator, in its attempt to maintain voltage, does not operate so as to overheat the synchronous motor field, which in turn involves either special attention, or the purchase of additional complicated relay apparatus.

If the Tirrill regulator is adjusted to maintain constant voltage at the sub-station, it cannot at the same time maintain constant power-factor on the synchronous motor, so that, if the contract above referred to required continuous operation of the synchronous apparatus at 100 percent, it would mean that the increasing loads on the railway would cause a drop in sub-station voltage, depending upon the constants of the transmission line, which would not be a satisfactory condition for other customers supplied from the same sub-station. These serious practical difficulties have resulted in the installation of few, and the operation of fewer Tirrill regulators for this purpose.

For practical purposes, then, the question becomes a comparison of the power-factor effects of the present standard type of synchronous motors with those of standard rotary converters, flat compounded, and both operating with only an occasional change in the setting of the shunt field rheostats. Railway load fluctuations are too rapid to permit frequent rheostat changes, which, moreover, are undesirable in the case of the rotary converter in the hands of the ordinary station operator, on the score of a possibly too great power-factor change, so that most electrical traction engineers prescribe, for ordinary operation at least, a constant setting of the shunt field rheostat once the machine is on the line.

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*See article on "Power-Factor Correction by Rotary Converters Is Hazardous," in the JOURNAL for Feb., '12, p. 150.

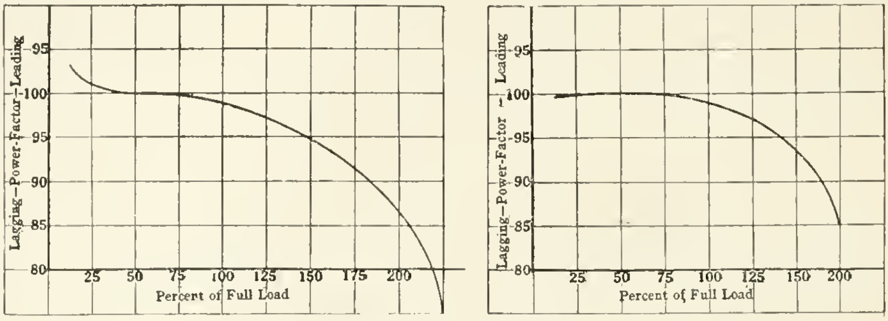
Although the superiority of the synchronous motor is undeniable where great power-factor corrective effect is essential, it is, nevertheless, questionable whether it is often necessary for the converting apparatus to have great power-factor corrective capacity; where this effect is required only in smaller amounts, the rotary converter will often possess an advantage.

The shunt-wound rotary converter possesses three inherent advantages, in this connection, over the shunt-wound synchronous motor. First, it is subject to less armature reaction, which means less tendency to decrease the counter e.m.f. with an increase of load. Second, the self-excitation of the converter tends to maintain the relative values of the line voltage and machine counter e.m.f. Both of these effects tend to allow less power-factor variation of the machine with constant excitation, but varying line voltage, than is the case with the synchronous motor. Third, as a rotating-armature machine, the converter may easily be compounded, which is a much more complicated operation with the synchronous motor, of the common rotating field type. The compounding, or the lack of it, forms the basis of the differences in the power-factor behavior of the two present standard types of machines. Resort to a rotating armature for the synchronous motor would allow readier compounding, with concomitant advantages.

A study of the problem presented by the operating conditions in most situations, seems to indicate that from the standpoint of the railway company, the rotary converter is preferable, and very frequently this is true also for the transmission company under the practical manner of operating outlined above.

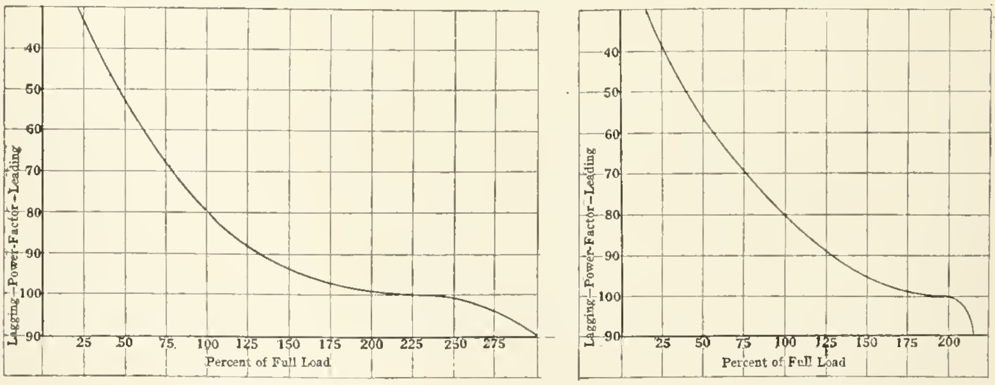
To bring out this idea more clearly, it will be profitable to study the inherent power-factor characteristics of the two machines, and the effects of such loads on a transmission system. It should be understood that no attempt is being made herein to disparage the installation of the synchronous motor per se, but rather to show that the rotary converter often possesses superior advantages with respect to power-factor correction.

As the load on a synchronous motor increases, its power-factor, if leading at no-load, tends, with constant field, to lead less and less, and to pass through unity to lagging values dependent on all the conditions involved. Fig. 1 illustrates this point in the case of a 500 kw motor-generator set, the synchronous motor being wound for 2 400 volts, three-phase, 60 cycles. Constant line voltage is assumed, and a setting of the field rheostat such as will produce 100 percent power-factor at half load on the direct-current generator. Here from a leading power-factor of 97 percent at 12 percent direct-current load, we have a swing to 75 percent lagging power-factor at 225 percent direct-current load. This tendency is modified largely by the percentage of leading power-factor load, and also by the



FIGS. 1 AND 2—POWER-FACTOR VARIATION WITH LOAD OF A SYNCHRONOUS MOTOR

Constant field excitation of a value to give 100 percent power-factor at 50 percent generator load. Fig. 1—Constant applied line voltage. Fig. 2—Line drop of ten percent at full load.



FIGS. 3 AND 4—POWER-FACTOR VARIATION WITH LOAD OF A SYNCHRONOUS MOTOR

Constant field excitation of a value to give 80 percent leading power-factor at full load on the generator. Fig. 3—Constant applied line voltage. Fig. 4—Line drop of ten percent at full load.

amount of alternating line-drop, for leading power-factor is only brought about by over-excitation; i.e. by an excitation which would give a terminal voltage to the machine, considered as a generator, greater than line voltage.

In Fig. 2 is shown a curve for the same motor, assuming an ohmic line drop of ten percent with full load on the direct-current generator and a motor excitation to give unity power-factor at half the direct-current load. Here we have a slight rise of lagging power-factor from 99.5 at one-eighth load to unity at half load, then dropping off again to about 85 percent lagging at 175 percent load. The total variation is less than in the former case; the line drop has helped to hold up the power-factor. The excitation is, however, some eight percent less than in Fig. 1, due to the lower line voltage at half load.

In Fig. 3 is shown the power-factor variation for the same machine excited for 80 percent leading power-factor with full load on the direct-current generator, and with constant line voltage; Fig. 4 is the same as Fig. 3, except that ten percent ohmic line drop is assumed with full load on the generator. In all of these cases, the tendency of the power-factor to droop toward lagging values is evidenced, though naturally to different degrees.

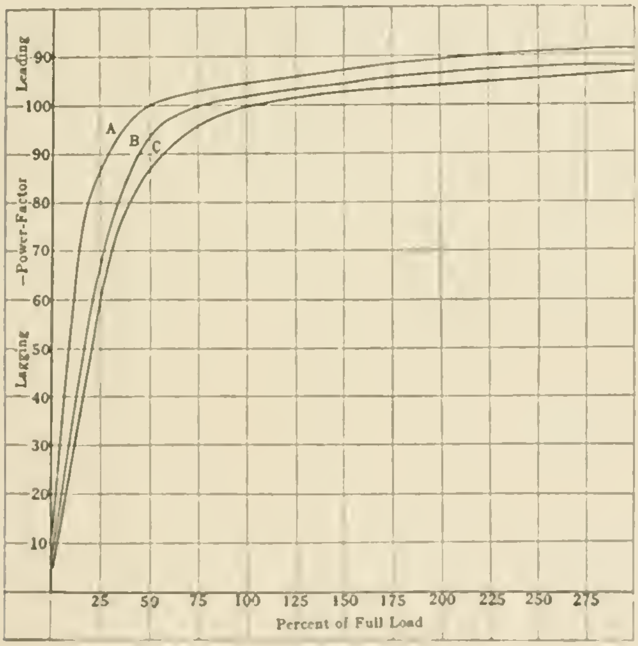


FIG. 5—POWER-FACTOR VARIATION WITH LOAD OF A ROTARY CONVERTER

Line reactance, 25 percent. Ohmic drop, 10 percent. Excitation set for 100 percent power-factor at, *A*—50 percent load; *B*—75 percent load; *C*—Full load.

From the inherent characteristics of a flat-compounded converter, the power-factor change as load comes on is from lagging to leading values, dependent upon the setting of the shunt-field rheostat, the relative amount of full-load armature and series field ampere-turns, the amount of ohmic line drop and the total reactance in the circuit connected to the converter.

A considerable amount of reactance is necessary to allow the converter to overcome the line drop throughout the entire circuit back to the generator bus-bars, which are assumed kept at a constant voltage by some form of regulator. In all commercial installations, a series field is also necessary both to allow the use of smaller reactance, and to cause, at heavy loads, that over-excitation which produces the flat compounding effect.

With standard converters, an ohmic line drop of ten percent for full load direct-current, a total alternating-current circuit reactance of 25 percent, and a shunt-field rheostat setting to produce 100 percent power-factor at 50, 75 and 100 percent loads respectively, the corresponding power-factor variations from no load to 300 percent load are given in Fig. 5, these curves being carried beyond the range of present standard lines of machines to show their behavior under extreme conditions. While the no-load power-factors have very low lagging values, it should be remembered that under these conditions, the total current taken from the line is very small, both because the no-load losses of the converter are smaller than those of the motor-generator set, and also because the no-load converter current is a smaller percentage (26.5 percent) of full-load than is true for the synchronous motor excited to operate at 80 percent leading with full load (72.5 percent) on the generator.

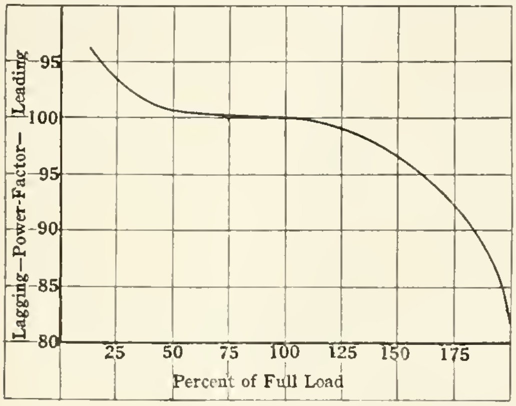


FIG. 6—POWER-FACTOR VARIATION WITH LOAD OF A SYNCHRONOUS MOTOR

Constant field excitation of a value to give 100 percent power-factor at 100 percent load on the generator. Line drop ten percent at full load.

In Fig. 6 is shown the power-factor variation for the synchronous motor excited for 100 percent power-factor with full load on the generator, assuming ten percent line drop for the same load. It is interesting to compare the integrated values of power-factor for the various curves, for generator loads from one-eighth to one and three-quarters, as shown in Table I. These figures indicate that the converter has a decided advantage in maintaining an integrated power-factor of unity, as required by the quotation from the contract cited above, assuming always a constant setting of the shunt-field rheostats, such as to give unity power-factor at lower loads than 100 percent, as is the increasing tendency for interurban service, which is of the sort most often making use of power from long transmission systems.

Turning now to the second point of view, namely the effect of the railway appartus on the transmission company's generator power-factor and voltage, it is clear that, in the day time, when the railway load is heaviest and when the power-factors of the transmission company's other loads are lowest, due both to the lightly loaded condition of lighting transformers and the power loads, consisting largely of induction motors, the characteristic rotary converter curves are of the rising power-factor kind; thus the effect will be to better the power-factor of the system, and vice versa.

Although the power-factor of the rotary converter is very low at light loads, the total energy demand from the system is also light, so that the total current is small, and the tendency towards line drop on the sub-station bus-bars is correspondingly small. Moreover, when the railway load becomes heavy, the converter power-factor is leading; and, if the converter circuit is provided with the proper amount of reactance for flat compounding, the effect of this reactance tends to hold up the line voltage at leading power-factors, counteracting the effect of ohmic drop; this reactance effect being proportional to the alternating current drawn from the line, i. e., to the direct-current load. In short, when the railway load is heaviest and such as would, from the standpoint of current alone, tend to cause greatest line drop, the power-factor takes on a value which tends to oppose the line drop.

TABLE I—INTEGRATED POWER-FACTORS FOR SYNCHRONOUS MOTORS AND ROTARY CONVERTERS

Percent Line Drop	Power-Factor at Load Given in Next Column, Percent	Normal Output, Percent	Integrated Power-Factor, Percent
	Synchronous Motors		
0	100	50	98.16 lagging
10	100	50	97.24 lagging
0	80	100	70.7 leading
10	80	100	73.1 leading
10	100	100	99.2 lagging
	Rotary Converters		
10	100	50	98.42 leading
10	100	75	95.3 lagging
10	100	100	91.25 lagging

Just the reverse conditions obtain for the synchronous motor; at times of light railway load and leading power-factor, the current, while tending to improve the line conditions from the power-factor standpoint, is not very effective because of its small value. When the railway load is changed to heavy overloads, requiring more current from the line, then the power-factor has changed to lagging values, so that, as it were, both the current and power-factor conspire to increase the line drop.

At night, when the railway loads are generally much lighter and when the other loads of the transmission system are of considerably higher power-factor, the effect of the line charging current becomes more pronounced and may produce a leading power-factor in the generators. If the average load of the railway converter is so light as to involve lagging power-factors, the corresponding currents will tend to decrease the leading wattless components of the system, or in other words, keep the power-factor near unity. On the other hand, even at light loads on the synchronous motor, the currents having leading power-factors are relatively heavy, due to the over-excitation, and tend to increase the lead of the main station power-factor, which is not desirable.

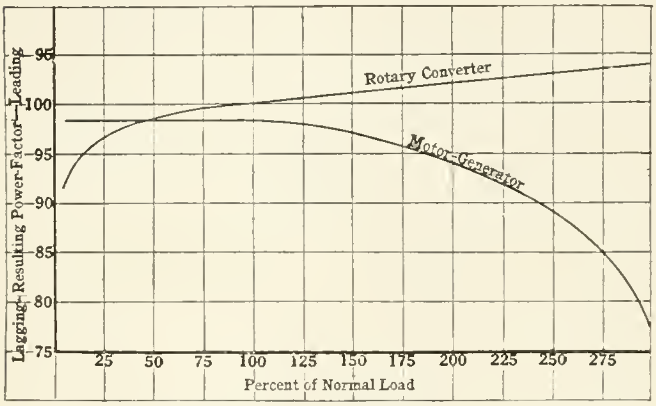


FIG. 7—COMPARISON OF EFFECT ON GENERATOR POWER-FACTOR OF ROTARY CONVERTERS AND MOTOR-GENERATOR SETS

Combined with an assumed day load of 4 000 kw at 80 percent power-factor and 2 100 k.v.a. charging current.

These effects are best brought out by reference to one or two examples:—

Assume first, a central station having a combined lighting and industrial load, apart from the railway load, of 4 000 kw. at 80 percent power-factor, or 5 000 k.v.a.; assume further, a proposed railway load of eight 400 kw rotary converters or motor-generator sets of characteristics similar in general to those previously mentioned; that is, with excitations to produce 100 percent power-factor at 50 percent load; assume further, a charging current corresponding to 2 100 k.v.a. Fig. 7 shows the effect on the power-factors of the generators due to either combination as the railway load increases. With the converter running idle, the power-factor is a trifle above 91 percent, from which it rapidly rises, passing 100 percent at about normal load, and reaching a value of about 96 percent leading, at 200 percent overload. With the motor-generator sets, the power-factor holds a steady value of about 98.5 percent up to approximately the full-load point, from which it drops off as the overload condition of railway load comes on.

Suppose again, it has been proposed to install in a sub-station, a transformer bank of larger capacity than necessary for the railway converting apparatus, with the idea of using the excess capacity for supplying local lighting and power load, for the former of which, at least, constancy of voltage is of prime importance. The effect of the railway load on such a transformer, when carried by rotary converters in one case and by synchronous motors in the other, is shown in Fig. 8. A transformer bank of 500 k.v.a. is assumed, having capacity, therefore, sufficient for 100 k.v.a. lighting in addition to the 400 kw required for the railway load. This transformer is supposed to step down from 60 000 to 2 300 volts for the synchronous motors or to the appropriate voltage for the converters, and in either case, Fig. 8 shows the conditions on the low tension side of the distributing system reduced to 110 volts. The actual bus-bar voltage is plotted against the increase in the railway load in percent. In the case of the converters it is seen that the voltage gradually rises from an initial value of 108.8 volts with the converters running light, to a value of about 110.8 at 100 percent overload. In the case of the motor-generator sets, from an initial value of 109.9 volts, the voltage drops gradually at first, more rapidly later, to a value of about 104.4 volts at 100 percent overload on the set. The effects of ohmic and reactance drop in the transformers were included in both cases, but the high tension line voltage was assumed constant, since the effect of the load on a single sub-station only was being investigated, and the amount of current drawn would produce very little voltage drop on so large a transmission system. If, however, the effect of line drop had been included, it would only have accentuated the tendency shown in Fig. 8.

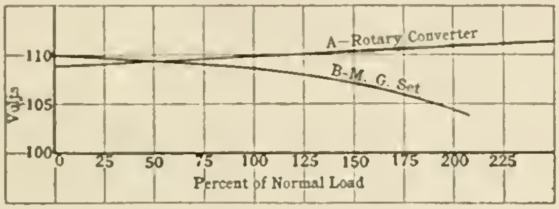


FIG. 8—COMPARISON OF EFFECT OF A 400 KW ROTARY CONVERTER AND A 400 KW MOTOR-GENERATOR SET

On the voltage regulation of a 110 volt bus of a lighting system fed from 500 k.v.a. of transformers carrying a variable railways load, and a constant lighting load of 100 k.v.a. No load voltage, 110 volts. Voltage with 100 kw lighting load, but zero railway load, 108.9 volts.

These two examples will give an idea of the general tendency. The practical results will vary with change in the assumptions necessary for calculation.

WAGE SYSTEMS.*

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Westinghouse Electric & Mfg. Company

This is the eighth of a series of articles on the general subject of works management, which was begun in the April issue.

EACH YEAR witnesses renewed effort either to eliminate more or less obvious defects in existing wage systems or to develop more nearly perfect ones. While there will without doubt be unanimity of agreement with the inference contained in this statement that the ideal system has not yet been devised, there may perhaps be some exception taken to the further statement, equally true nevertheless, that there are a number of wage systems already extant, which, when properly selected and impartially applied, will be found capable of fulfilling normal conditions very satisfactorily, leaving little additional to be desired. It is ever the variable human element, sometimes the employer, as often the employe, refusing to measure up to rational standards, which renders it so exceedingly difficult to devise methods that will prove universally acceptable under all conditions likely to arise. Much of the difficulty is due no doubt to the common, though mistaken feeling that the interests of employer and employe lie wide apart; and until this situation is materially changed, there will continue to be a heavy handicap on every effort looking to the development of an ideal wage system. The real interests of employer and employe are, as a matter of fact, identical. The legitimate aim of each should be to make a fair profit on his capital investment, represented in the case of the employer by his product and on the part of the employe by his labor. The employer desires low costs, the employe, with equal fairness wants high wages. If these two features can be attained simultaneously, both parties should and must be fully satisfied.

It will be seen from the preceding that any real solution of the problem of the ideal wage system must bring with it correct answers to the two questions, "What constitute low costs?" and "What are high wages?" Both of these terms are capable of considerable misconstruction and, therefore, in need of more clean cut definitions, which are not attempted in this article.

All wage systems may be placed in one of four groups: day work, piece work, premium or bonus work and gain or profit sharing.

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*Taken in part from an article by the author in the *American Machinist* for June 13, 1912.

DAY WORK

Day work is the oldest form of wage payment, and a very large percentage of skilled and unskilled labor throughout the civilized world operates under this system. It will be observed further, especially in the larger concerns whose product is more or less diversified, that even when some other form of wage system has been introduced, a considerable portion of the labor will still continue to be paid by the hour, day or shift.

Under this method the quantity of work to be completed in any given time is not specified; moreover, the hourly rate is the same regardless of the number of hours worked in a day. Expressed as a simple equation,

Hourly rate × Number of hours = Wages.

This relation has been plotted in Fig. 1. Day work, therefore, offers no inducement for any increase in output over a recognized basis; the natural tendency in consequence must be for the average workmen not to exert themselves, further than to turn out just sufficient work as will, in their own estimation, satisfy their immediate superiors and so insure retaining their jobs. From the fact that no time or price is stipulated for the completion of a piece of work, it has been argued that quality should be of the highest and in theory this may be true.

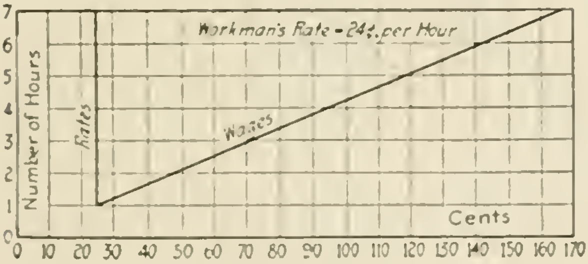

FIG. 1—DAY WORK

Hourly rate × No. of hrs. = wages.

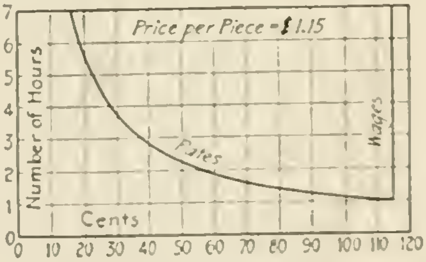

FIG. 2—STRAIGHT PIECE WORK

Price per piece × No. of pieces = wages.

For ready comparison, these and all succeeding charts have been plotted on the same basis; workman's rate — 24c per hour; piece prices — $0.96—$1.152—$1.144; time limit — 6 hours; standard time 4 hours.

In many shops, working under so-called scientific management, and where an "incentive" is offered to the workmen to put forth extra effort to increase their output, it is the practice to maintain records of productive labor efficiencies, either of the individual workmen in a department or of the department as a whole, efficiency being considered as the ratio between the time each job should take and the time actually taken on a job. For example, if twelve hours were actually taken to do a job and ten hours had been set as the time in which the job should be done, then the efficiency of the workman doing this particular job would be set down at 83 percent. If, however, no time had been set in which the job should be done, possibly because it was quite special and not likely to repeat itself, and the work was done by day work in twelve hours, the efficiency would be arbitrarily figured at 65 percent or even lower, it being assumed that the job could have been done in 7.8 hours had an "incentive" existed to do it in such time. This then is an indication of what authorities on the subject think of day work as compared with other systems of wage payment. It follows from what has been said, therefore, that under day work, increased output can be obtained, as a rule, only by increased supervision, and the cost per piece must accordingly be more expensive than under any other form of wage system. Notwithstanding this, it is, in many cases, the only logical one to use; as for instance, in work such as die, template, jig or pattern making, where no two pieces are in any wise alike and where it would be impossible to determine within accurate bounds without the expenditure of a prohibitive amount, either piece prices or premium time limits. From the accounting standpoint, day work is less complicated than any other form of wage system as far as figuring the pay-roll is concerned; but, in the matter of figuring costs, it is not so simple as piece work, though rather more so than premium work.

STRAIGHT PIECE WORK SYSTEM

Straight piece work is the second oldest form of wage system. Payment is based solely on the piece, as its name implies, and since the time employed is not specified, it will thus be seen to be the very opposite of day work. It is ranked only by day work in the matter of age and is without doubt next to it the most commonly used method. The wages earned may be written,

$$\text{Piece work price} \times \text{Number of pieces} = \text{Wages.}$$

The price per piece is the same, regardless of the time employed, as indicated in Fig. 2. It will, however, be observed that the wages or the hourly rate of the workmen increase with decrease of time taken, thus indicating one way in which the employe may receive higher and higher wages for his labor. At the same time the employer will obtain lower and lower costs in his product, for, while the price per piece undoubtedly remains the same, the output in unit time increases, thus lessening all indirect expense, such as supervision, heat, light, water, etc. For the reason that the workmen take all of the direct profits, the employer not sharing them as in premium work, but being restricted simply to the indirect profits by a reduction of indirect expense, the application of the piece work system is confined to rather narrower fields than would otherwise be the case. Obviously the employer cannot be expected to use this system in connection with work in which the details have not been thoroughly standardized and in which accordingly, there would be possibilities of error in the setting of piece work prices. It may, of course, be argued by some that errors are easily rectified by "cuts" in the prices, if too high; since, if the prices are too low, the workmen insist that they be raised. The indiscriminate cutting of piece work prices due to the loose and unscientific way in which they have been set in the past, has undoubtedly been the cause for much of the abuse heaped upon the piece work system, to which it is hardly entitled. Regardless of the logic involved, it has been demonstrated that for best results, low prices must be raised, but high prices should not be lowered unless the method of making the piece is changed, in which case a revision in price is permissible. An argument that has been advanced against piece work, in common with all other wage systems having an "incentive," is that the increase in production is likely to be accompanied by a decrease in quality. While this tendency undoubtedly exists, it can be, and is effectually guarded against by a properly enforced scheme of inspection, with penalties in the shape of rejection of the defective work until the defects have been corrected by the workmen. Another argument against this system, and a stronger one than the preceding, is that it fails to take into account the varying price of labor. In a time of business depression, the volume of work is at its minimum and the demand for labor in conequence is not so great as at other times. The price of labor, therefore, falls, but the employer, though needing to make the utmost of the situation in order to continue to obtain his share of such business as is being transacted, cannot avail himself of the opportunity without cutting the piece work prices. He must also reduce the quantities usually manufactured, but in so doing there is taken from the workmen the ability to make normal wages. In either case, dissatisfaction will be the result, with a possible temporary reversion to day work.

A similar situation will in turn exist when business is above normal. The demand for labor then increases, producing a rise in the price; and unless piece work prices are increased to correspond, the workmen once more feel that they are being underpaid.

From the accounting standpoint no system is equal to piece work in the ease with which costs may be figured, though it is becoming more and more the custom, as previously stated, to check every job against a base or standard time, thus taking away from piece work the simplicity which has heretofore appealed to accountants, and putting it more nearly on a basis with premium work.

MANCHESTER PIECE WORK SYSTEM

The idea of guaranteeing a day's wage is not the usual custom under piece work systems. However, this is now being done to some extent, the hourly day rate being that paid for the class of labor involved and being fixed at the time of hiring the workmen. The scheme has been designated as the Manchester piece work system, possibly for the reason that the idea may have first been carried out in Manchester, England. Sometimes the day rates are guaranteed only when the workmen are delayed by causes beyond their control, such as stoppage of the machinery, non-arrival of material, bad crane facilities, hard castings, etc.

DIFFERENTIAL PIECE WORK SYSTEM

Mr. F. W. Taylor, the foremost exponent of scientific management, has devised a system of piece work in which several graded prices are applied to a single job, a maximum one when done within a certain minimum time, a low price when this time limit is exceeded, and perhaps a minimum price if the work is imperfect yet passable. There may be even further classifications, as the scheme does not confine itself necessarily to any particular number of prices. The minimum time is in each case based on the performances of the exceptionally fast and skilled workmen, the idea being to retain only such on the work by making the maximum prices sufficiently attractive to them, at the same time placing the other prices so low that the average workmen will not be satisfied, and will either secure the maximum prices or quit the work of their own accord and seek some other operations for which they are better fitted. As in straight piece work the same formula applies.

High or low piece work price × No. of pieces = Wages.

The marked variations between the hourly rates when the work is done in the minimum time and also when such time limit is exceeded, are shown in Fig. 3.

In general, the same arguments for and against straight piece work apply to this system, with the additional fact that the multiplicity of prices adds to the difficulties of accounting. The Taylor system stood originally quite alone in requiring a scientific analysis of each elemental operation in connection with a job, so that an intelligent piece work price could be set once and for all without the necessity for "cutting" it later. However, this is now being done largely in other systems of wage payment as well and is no longer a special feature differentiating this system from others.

GROUP PIECE WORK SYSTEM

Piece work may be applied at times with very considerable advantage to groups of workmen and in a variety of ways. A number of workmen may be given a piece work job, the price paid being divided among them on the basis of their fixed hourly day rates (mentioned under the Manchester piece work system) and the number of hours worked by each. Or, a job may be given to a group, the charge hand being paid the difference between the piece work price and the wages at day rates of such helpers as he may have. Though it is usual for the helpers to be assigned to him, he is sometimes free to hire the class of labor required and to pay them either on a day work or a piece work basis as may seem to him desirable.

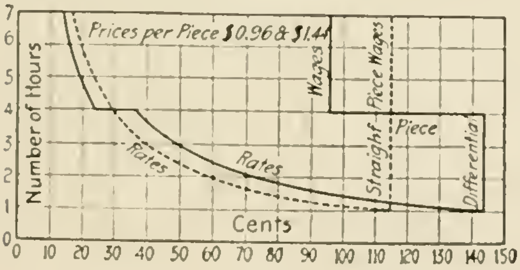

FIG. 3—DIFFERENTIAL PIECE WORK

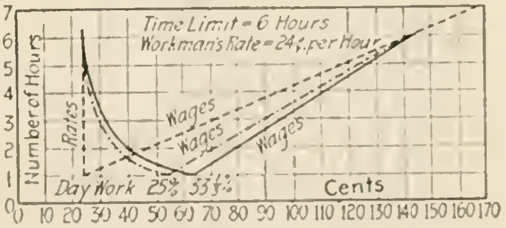

FIG. 4—HALSEY PREMIUM SYSTEM

Fig. 3—Price per piece × no. of pieces = wages.

If the piece is completed within the allowed time, the higher piece work price is paid; the lower price is paid if the allowed time is exceeded or if the piece is not up to the standard quality of workmanship, though passable.

Fig. 4—Earnings = wages at day rate for time taken plus a premium which is equal to the day rate for 1-4, 1-3 or 1-2 of time saved.

[Time taken + X (time limit — time taken)] × hourly rate = wages
Where X = any fraction as 1-4, 1-3, 1-2 or 0.4, etc.

For best results it is advisable to keep the number of workmen in a group within a limit, say, of twelve, the idea being to create a feeling of partnership among them, the men taking an interest and helping one another over the hard spots or where difficulty or bad luck overtakes any of them. One of the chief arguments against the grouping of men is that it kills individual initiative, but the facts prove the contrary where the groups are in small numbers, as it has been demonstrated that the men actually earn higher wages when working collectively than when working individually.

PREMIUM OR BONUS SYSTEMS

The most recent of the fundamental groups of wage systems is premium or bonus work. It is a combination of day work and piece work in that it incorporates the leading features, namely, time and quantity of these other two systems. The workmen are guaranteed their day work wages; and, in addition they are offered an "incentive" in the shape of a bonus or premium for extra effort over and above that required for the average day's work, providing, however, that such effort results in the production either of increased quantity in the given time, or in standard quantity in less than the given time.

HALSEY PREMIUM SYSTEM

The earliest of the many premium systems now before the public is that of Mr. F. A. Halsey, until recently editor-in-chief of the *American Machinist.* It was devised by him in 1890, while superintendent of the Rand Drill Company, Sherbrooke, Canada. In the scheme as originally outlined the workmen were offered premiums equal to one-third or one-fourth of their hourly rates, for every hour saved over and above their previous performances. "Making the hourly premium less than the hourly wages is," as stated by him, "the foundation stone on which rest all the merits of the system, since by it, if an hour is saved on a given product, the cost of the work is less and the earnings of the workman are greater than if the hour is not saved, the workman being in effect paid for saving time."

As now generally operated, a time is estimated for the performance of each job after careful study of the conditions, which time is known as the base or standard time. It is usually the time which the average skilled workman should take to do the job when working as he ought regularly to work, not soldiering. Sometimes the exceptionally fast instead of the average workman serves as the model. No matter which is thus taken, there is added to the base or standard time an "incentive" (less if the average workman, greater if the exceptional workman has been the model), the sum of these becoming the time limit or allowed time. If now a job is done in less than the time limit, the amount saved is divided between the workman and the employer in a pre-arranged proportion. Should, however, the job be done either exactly in the time limit or in excess of it, the workman receives but his regular day work wages for the time employed on the job. In the operation of this system, it is customary to guarantee that time limits once set will not be altered unless the method of doing the work is changed; and the day work wages are also guaranteed, as just intimated. It is, of course, quite evident that although there may be jobs which have the same base or standard time, it does not necessarily follow that they should likewise have the same time limits; for example, one job may be done under favorable conditions, such as good tools and light, a clean room with uniform temperature, etc., while another job may require to be performed over a hot fire, in dirty quarters and with changing temperature. In the latter case it is but fair to add a greater "incentive" to the base time than in the first case, thus making the time limit greater.

What the percentage relation should be between the base or standard time and the "incentive," will depend upon the relation existing between the prevailing day rates of the district in which any particular work is located and those of the works in question. If the latter are below the level of the day rates of the district, then the "incentive" should be higher and conversely. What constitutes a proper premium or bonus has been very fairly expressed by Mr. H. C. Gantt, thus: "It is such a bonus as will make the workman feel that he is fully compensated for the extra exertion he puts forth. Judged from this point of view, it is evident that the bonus depends upon the severity of the work. It varies as a rule from 20 to 50 percent of the day rate. Task (bonus) work does not necessarily mean more severe work, but it does mean more continuous work and work under more favorable conditions, which always produce greater efficiency."

The following formula applies in figuring wages under the Halsey premium system:—

[Time taken + N (Time limit — Time taken)] × Hourly rate = Wages. Where N = any fraction as ¼, ⅓, ½, etc.

Two curves of wages and hourly rates, in which the premiums are 25 and 33 1/3 percent, respectively, are shown in Fig. 4; that is, the workmen receive premiums equal to ¼ or 1/3 of the time saved, at their day rates. These curves, it will be observed, indicate another way, radically different from any form of piece work, in which low costs and high wages may readily go together. The features which commend this system to the workmen most strongly are the guaranteed day wages and the non-cutting of time limits. On the part of the employer, the strongest features are the share in the direct savings and the ability to grade the workmen on jobs without any cutting of time limits. It will be readily appreciated that in all works, there are improvements going on continuously, including increased transportation and handling facilities, additional cranes with higher speeds, better lighting and the like. These are of such a nature that while assisting the workmen towards increased output, they are not usually sufficient to warrant any change in time limits, especially as most of the improvements are introduced gradually. Under almost all premium systems the employer shares in these direct benefits along with the workmen, which is not the case in piece work. The ability to grade workmen is similarly a very important feature. There are many instances in which apparatus, long standardized, may be in danger of being supplanted by a competitor's apparatus selling at lower prices. To meet this situation, or even to anticipate it, the costs may ofttimes be reduced by gradually training lower hourly rated workmen to the work, the higher priced workmen being placed on the newer and more intricate products and thus the life of some one or more specialties continued for a number of years with advantage to all parties concerned. Still another feature of premium systems which should commend them to the employer and to the workmen is the variation in the hourly rate with the rise and fall in the labor market. They are, on the other hand, open to the same criticism as piece work, namely, that there is a tendency for quality to fall off with increase in output, but which, as previously stated, may be effectively guarded against by a proper system of inspection. A further argument against them is that the greater the output, the less the cost per piece to the employer, therefore, the workmen receive less and less per piece, whereas the effort required increases with each piece. From the accounting standpoint premium systems are more complicated both in the matter of figuring costs and workmen's pay, than other systems of wage payment.

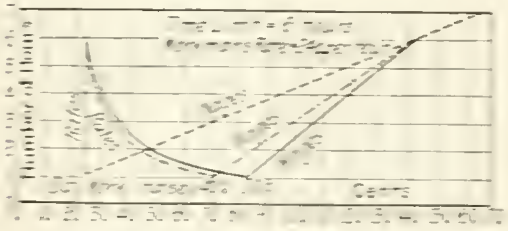

FIG. 5—WEIR-HALSEY SYSTEM

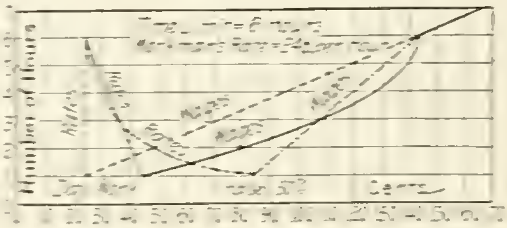

FIG. 6—ROWAN PREMIUM SYSTEM

Fig. 5—This system is identical with the Halsey System except that the workmen always receive 50 per cent. of what they gain over their day work time.

Fig. 6—Earnings = wages at day rate for time taken plus a premium which is calculated upon the time taken in the proportion of time saved to time limit.

$$\left(\text{Time taken} + \frac{\text{time limit} - \text{time taken}}{\text{time limit}} \times \text{time taken}\right) \times \text{hourly rate} = \text{wages.}$$

WEIR-HALSEY PREMIUM SYSTEM

At the works of Messrs. G. & J. Weir, Glasgow, Scotland, a slight modification of the Halsey system was said to have been first introduced, consisting in fixing the premium for all jobs at one-half of the time saved. It is more properly the Halsey 50 percent system. Almost the same formula is used as in the Halsey system:—

[Time taken + ½ (Time limit — Time taken)] × Hourly rate = Wages. This may be expressed shortly for accounting purposes as (Time taken + Time limit) × Hourly rate ÷ 2 = Wages.

The variations in hourly rates and wages are shown in Fig. 5.

MACLANE DOUBLE RATE PREMIUM SYSTEM

A two rate premium system modeled somewhat after differential piece work has been suggested by Mr. H. F. MacLane, of the Westinghouse Electric & Mfg. Company. Briefly, it may be said to consist in the payment of either of two rates, from time to time as conditions warrant. All workmen upon being hired, would be given two day rates, starting on the lower of the two and thus continuing until any month's pay showed an average of base or standard time to have been made on all jobs for such period, when the higher day rate would then be awarded for the following month. If base or standard time was again averaged for this month by the workman, the higher rate would be continued; but if not, the lower rate would again come into force for the next succeeding month. The usual arguments for and against premium systems apply in this case with the additional one of increased complexity in figuring costs as well as the workmen's pay.

ROWAN PREMIUM SYSTEM

Mr. James Rowan, of Messrs. David Rowan & Sons, Glasgow, Scotland, has developed a premium system to overcome an objection sometimes made against the Halsey (50 percent) system and almost invariably urged against piece work, namely, that the interests of the employer are not sufficiently conserved against serious errors in the setting of time limits or piece work prices. Under the Rowan system, a time limit is placed on each job and the workmen receive their hourly rates for the time actually engaged on it plus a premium which is figured on the actual time in the proportion of the time saved to the time allowed.

The formula for the caluculation of wages is:—

$$\left[\text{Time taken} + \frac{\text{Time limit} - \text{Time taken}}{\text{Time limit}} \times \text{Time taken}\right] \times \text{Hourly rate} = \text{Wages.}$$

The variations in the hourly rates and wages along with the curves of the Halsey 50 percent system are shown in Fig 6. A comparison of this system with the Halsey 50 percent system will show that the original idea has been accomplished only in part; for, it will be noted that while the workmen make less under it than under the Halsey system above "time and one-half," the conditions are reversed below this line. As the majority of jobs are, however, usually of the latter kind, the net result would seem to be greater average costs than under the Halsey system. Aside from this feature, the difficulty of understanding and of figuring the premium would seem to constitute a serious objection. The system several years ago received the endorsement of the Amalgamated Society of Engineers, one of the largest labor organizations in Great Britain, through their general secretary, Mr. G. N. Barnes. Comparing the Halsey and the Rowan systems, he says of the former: "These increasing gains with increasing product would still leave temptation in the way of the employer to cut the time limits; and, indeed, would seem to justify it, having regard to estimated and actual times of doing a job in extreme cases. Mr. Rowan's system, on the other hand, gives the man an increase of wage equal to the saving effected from the time limit." There is considerable force in this criticism although it is not confined to the Halsey system, but applies to all premium systems and to piece work as well; for, while neither time limits nor piece work prices should be altered after once being set, unless the method of doing the work is changed, the employer is not prevented from reducing the time limits or piece work prices on new work, even when it is almost identical with other work on which much higher limits or prices have previously been set. However, it is manifest that no employer can afford to perpetuate obvious errors, so that it is hardly right to expect, in the event of an error having been made in the setting of a time limit or a piece work price, the same limit or price should be used again on similar work. The preceding remarks lend emphasis to the statement, made in an earlier paragraph, that any wage system, to be successful, must be treated fairly both by employer and employe, each with the feeling that the other is perfectly honest, in his intentions at least, even if there seem to be occasional evidence to the contrary.

CARDULLO DIMINISHING PREMIUM SYSTEM

A system has been developed by Mr. Forrest E. Cardullo, professor of shop work in Syracuse University, which is quite similar to the Rowan system except that attempt has been made to conserve the interests of the employer still further, as is indicated by the name of the system itself, and which is at the same time rather against its successful use.

The formula for figuring wages is almost identical with that of the Rowan system, except that an additional constant is introduced:—

$$\left[\text{Time taken} + \frac{\text{Time limit} - \text{Time taken}}{N \times \text{Time limit}} \times \text{Time taken}\right] \times \text{Hourly rate} = \text{Wages.}$$

When N = any whole number.

The variations of hourly rates and wages and likewise a comparison with corresponding curves of the Rowan system are shown in Fig. 7. Naturally the arguments for and against the Rowan system apply to the Cardullo system with added force

HALSEY-ROWAN PREMIUM SYSTEM

In an endeavor to overcome one of the criticisms made against the Halsey (50 percent) and the Rowan system, Mr. Robert Goldmann has suggested that they be combined, the former being used for the lower half of the scale, the latter for the upper half, as shown in Fig. 8. In so doing the danger under the Halsey system of excessive premiums due to wrongly set limits would be avoided; at the same time the relatively large premiums for small gains under the Rowan system would be eliminated. While it seems that this system would accomplish its purpose, it is not known that it has been tried out practically and the accounting features are certainly rather complicated.

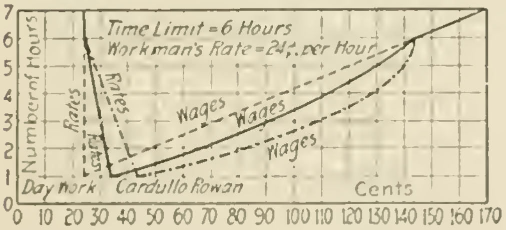

FIG. 7—CARDULLO DIMINISHING PREMIUM SYSTEM

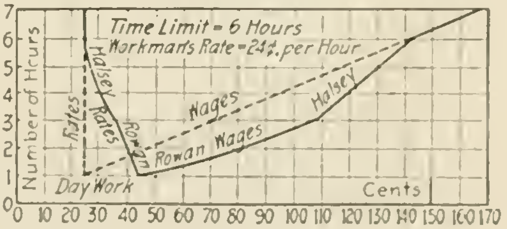

FIG. 8—HALSEY-ROWAN PREMIUM SYSTEM

Fig. 7—Earnings same as in Rowan System except that only a fractional part of the premium is allowed.

$$\left[\text{Time taken} + \frac{\text{time limit} - \text{time taken}}{N \times \text{time limit}} \times \text{time taken}\right] \times \text{hourly rate} = \text{wages.}$$

Where N = any whole number, as 2, 3, etc.

Fig. 8—This is the Halsey System for the first half (lower gains) and the Rowan system for the second half (higher gains).

GANTT BONUS SYSTEM

Mr. H. C. Gantt, long associated with Mr. F. W. Taylor in his earlier investigations of shop management, has devised a system of wage payment in which each workman who is successful in doing all of his work for a complete term within the time limits, is given a substantial bonus. In the contrary event, he is paid a day rate wage for the time employed. The foreman, too, is usually given a bonus for each workman under him who earns a bonus; and an additional bonus is awarded him if all of the workmen under him earn bonuses. It is thus doubly to the foreman's interest not to neglect any workman, but to see that all receive a share of his attention, especially in the matter of selecting the right kind of man for each job, in this way tending to stop a criticism, heard at some time or another under almost all wage systems, that certain favored workmen receive the so-called "nice" jobs. In this system the base or standard time is generally based on the performance of the exceptionally skillful workman, resembling in this respect the Taylor differential piece work system. It is open to the same arguments, for and against, as any of the other premium systems.

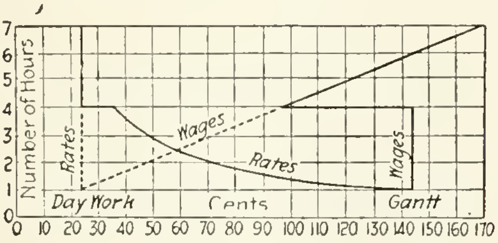

FIG. 9—GANTT BONUS SYSTEM

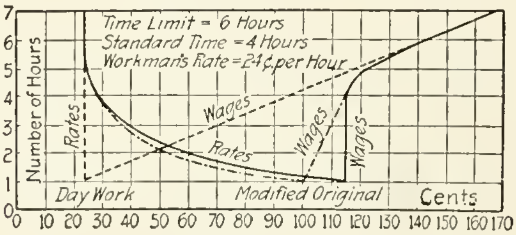

FIG. 10—EMERSON BONUS SYSTEM

Fig. 9—If the work is completed in standard time or less, Earnings = wages at day rate increased by 50 percent for standard time.

Standard Time x [hourly rate + (50 percent x hourly rate)] = wages.

Fig. 10—If work is completed in standard time or less

Original Scheme—Earnings = wages at the day rate for standard time plus a premium which is equal to 20 per cent of such wages.

(Standard time x hourly rate) + (20 percent x standard time x hourly rate) = wages.

Modified Scheme—Earnings = wages at day rate for standard time plus a premium which is equal to 20 percent of wages for time taken.

(Standard time x hourly rate) + (20 percent x hourly rate x time taken) = wages.

In either scheme, if the work is completed in excess of standard time, a premium is still paid (following a parabolic curve though any other curve might have been as logically taken) but it gradually diminishes until a point is reached where the time taken exceeds the standard time by 50 per cent, when premium ceases.

The formula for wages when the work is completed in standard time or less may be expressed thus:—

$$\text{Standard time} \times \left(\text{Hourly rate} + \frac{\text{Hourly rate}}{N}\right) = \text{Wages.}$$

When N = any whole number.

The variations in hourly rates and wages are shown in Fig. 9.

EMERSON BONUS SYSTEM

Another bonus system is that due to Mr. Harrington Emerson, originally in use on the Atchison, Topeka & Santa Fe Railway, but now installed in various other plants throughout the country, in a somewhat modified form. As first devised, it was the nearest approach to piece work of any of the premium or bonus systems in that all of the direct profits went to the workmen, the employer gaining but indirectly, that is, only by the reduction of factory expense due to increased production. It was, however, a premium or bonus system in that time limits instead of piece work prices were set on the work. The formulae for calculating wages under the two schemes, when the work is completed in base or standard time or less, are as follows:—

Original—$$(\text{Standard time} \times \text{Hourly rate}) + \frac{(\text{Standard time} \times \text{Hourly rate})}{5} = \text{Wages.}$$

Modified—$$(\text{Standard time} \times \text{Hourly rate}) + \frac{(\text{Time taken} \times \text{Hourly rate})}{5} = \text{Wages.}$$

In either scheme, if the work is completed in excess of the standard time, a premium or bonus is still paid, following a parabolic curve, to which portion the formulæ do not apply (though any other curve might have been taken as logically), but gradually diminishing until a point is reached where the time taken exceeds the base or standard time by 50 percent, when the premium or bonus ceases, after which straight day work is paid. Fig. 10 affords a comparison of the hourly rates and wages under both schemes. A feature on which considerable stress has very properly been laid by Mr. Emerson in connection with his system, though its application is not confined to it, but may be applied to all other wage systems, is the figuring of the productive efficiency of each workman. This consists in adding together the "time taken" by a workman on all jobs over a given period, likewise the corresponding "standard time"; then, dividing the total "standard time" by the total "time taken" to get the efficiency. This idea may be carried down to the individual job, if desired; or it may be applied similarly to any single department of a works and the productive labor efficiency ascertained of all the workmen in it, taken collectively, thus obtaining in a measure the efficiency of the foreman. It will, of course, be recognized in this connection, that the productive labor efficiency may exceed 100 percent, if "standard time" is based upon the performance of the average skilled workman and not upon the exceptionally skilled artisan.

PARKHURST COMBINATION PREMIUM SYSTEM

This is a system devised by Mr. F. A. Parkhurst, apparently identical with the original Emerson efficiency system, except that a straight line instead of a parabola is used for small gains.

COMPARISON OF WAGE SYSTEMS

A comparison of the various wage systems here discussed is quite difficult, as in some instances the performances of the exceptionally skilled workmen are taken in determining base or standard times; while in others, the performances of the average skilled workmen are used. The difficulty is encountered in attempting to decide how much these two bases differ. In comparing these several systems here, however, such differences have been ignored and the base or standard time is assumed to have been arrived at under the same conditions in all cases. In straight piece work the price is considered as being the same as in the premium systems when the piece is completed in the base or standard time. The Halsey 40 percent system is used in order to correspond with the 20 percent incentive of the Emerson efficiency system. In the Cardullo system, N is taken as 2, simply to distinguish it from the Rowan system. The bonus in the Gantt system is arbitrarily taken at 50 percent of the day rate for making standard time or better. Fig. 11 and Table I compare the several systems graphically and numerically.

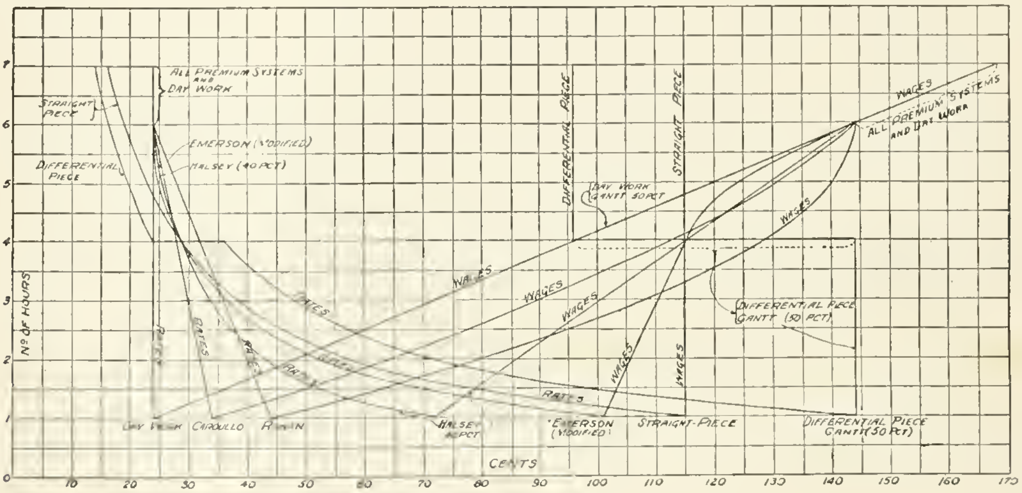

FIG. 11—COMPARISON OF WAGE SYSTEMS

Time Limit = time allowed within which work must be performed in order to earn premium; it is equal to the standard time plus an additional amount called an "incentive." Standard Time = time in which work should actually be done by a skilled man working as he ought regularly to work; in some systems this standard time is based on the exceptionally skilled workman; in others it is based on the average skilled workman; in this comparison no difference of this kind is observed. Time limit = 6 hours; standard time = 4 hours; workman's rate 24c per hour; piece prices = $0.96—$1.152—$1.44.

The same general plan may be followed in applying a premium or bonus system to groups, as to individuals.

GAIN OR PROFIT SHARING SCHEMES

Gain or profit sharing schemes are becoming more and more numerous and are varied in the extreme. They are perhaps applied more frequently to the office or non-productive force of an establishment than to the productive element. A number of years ago Mr. Henry R. Towne, of the Yale & Towne Mfg. Company, Stamford, Conn., manufacturers of keys, locks and accessories, developed and used successfully a very novel gain sharing scheme. As set forth by him, "the system . . . aims to afford a basis for alotting to the employes in a business, a share in the gain or benefit accruing from their own efforts, without involving in the account the general profits or losses of the business." Applied by him, an average cost per unit was first determined upon, after which any saving effected in the cost of the total output in a given period resulting from the efforts of the workmen themselves, was proportioned on the basis of 50 percent to the company, 40 percent to the workmen and 10 percent to the foremen. Each workman was

TABLE I—COMPARISON OF WAGE SYSTEMS

Time limit = 6 hours; standard time = 4 hours; workman's rate = 24c per hour; piece prices = $0.96—$1.152—$1.44.

Hours Worked	Day Work		Straight Piece		Differential Piece		Emerson [Mod.]	
	Wages	Hourly Rate	Wages	Hourly Rate	Wages	Hourly Rate	Wages	Hourly Rate
7	1.68	0.24	1.152	0.164	0.96	0.128	1.68	0.24
6	1.44	0.24	1.152	0.192	0.96	0.15	1.44	0.24
5	1.20	0.24	1.152	0.230	0.96	0.18	1.239	0.248
4	0.96	0.24	1.152	0.288	0.96	0.36	1.152	0.288
3½	0.84	0.24	1.152	0.328	1.44	0.411	1.128	0.322
3	0.72	0.24	1.152	0.384	1.44	0.48	1.104	0.368
2	0.48	0.24	1.152	0.576	1.44	0.72	1.056	0.523
1	0.24	0.24	1.152	1.152	1.44	1.44	1.008	1.008

Hours Worked	Rowan		Cardullo N=2		Gantt. 50 Per Cent.		Halsey, 40 Per Cent.	
	Wages	Hourly Rate	Wages	Hourly Rate	Wages	Hourly Rate	Wages	Hourly Rate
7	1.68	0.24	1.68	0.24	1.68	0.24	1.68	0.24
6	1.44	0.24	1.44	0.24	1.44	0.24	1.44	0.24
5	1.40	0.28	1.30	0.26	1.20	0.24	1.296	0.259
4	1.28	0.32	1.12	0.28	1.44	0.36	1.152	0.288
3½	1.19	0.34	1.015	0.29	1.44	0.411	1.08	0.308
3	1.08	0.36	0.90	0.30	1.44	0.48	1.008	0.336
2	0.80	0.40	0.64	0.32	1.44	0.72	0.864	0.432
1	0.44	0.44	0.34	0.34	1.44	1.44	0.720	0.72

guaranteed his regular wages, so that it is at once seen the workmen shared the profits, but were protected against possible losses. The workmen's share of the profit was divided among them on the basis of wages earned. It is understood this scheme is, however, no longer in effect.

One of the most original and liberal schemes of profit sharing is that in force at the Nelson Valve Company, St. Louis, Mo. This concern divides profits in excess of six percent among employes and customers, the former participating on the basis of salaries or wages, the latter on the gross profits resulting from their purchases.

The Crane Company, Chicago, Ill., makers of valves and valve fittings, have tried a number of profit-sharing schemes and about nine years ago fixed upon their present plan, which consists simply in giving annually to all employes excepting officials, an amount ranging from five to ten percent of their salaries or wages, depending upon the profits of the business for the last fiscal year. There is no requirement in regard to length of service.

The Lodge & Shipley Machine Tool Company, Cincinnati, Ohio, operate under a premium system and have in force a scheme of monthly profit sharing among the non-productive portion of their employes, including tool, pattern, drawing and cost departments. It resembles somewhat the one used by the Yale & Towne Mfg. Company, except in the percentage distribution of profits, 50 percent of the time saved going to the workmen, 25 percent to the foremen and the remaining 25 percent to the so-called non-producers in these non-productive or expense sections. In the productive sections, each foreman is credited with a bonus of five cents per hour for every hour saved from the time limit or allowed time on all jobs done by the workmen under him, being debited with 20 cents per hour for every hour any job is over-run, the difference between these two accounts constituting the bonus.

The leading criticism made against this method of rewarding employes is that the allotment of the profits once a year is too infrequent, though this does not hold in all cases, as for instance, at the Lodge & Shipley Machine Tool Company, where the allotment is on a monthly basis. An additional criticism is that the employes do not share in the losses. The principal argument in favor of gain or profit sharing is that it increases the loyalty, enthusiasm and esprit de corps of the entire force, a most desirable achievement and one the value of which it is impossible to measure in mere dollars and cents.

ELECTRICAL EQUIPMENT FOR AUTOMOBILES

C. E. WILSON

THE manufacture of electrical accessories for gas engines has become a large industry, especially within the last year. The value of the automobiles manufactured in the United States during the past year has been conservatively estimated at $500 000 000. This means a $35 000 000 business for the manufacturers of electrical apparatus.

IGNITION

The first application of electricity to the gas engine, the production of a spark for ignition purposes, was fundamental. The first ignition device consisted of a set of primary batteries with a suitable high tension coil, interrupter and distributor. The magneto, a small alternating-current generator of the permanent magnet type, was a later development which largely supplemented the older primary battery arrangement as a source of energy for ignition. Made in the form of a "high tension magneto," with the primary and secondary windings wound directly on the armature core and used for an induction coil as well as a generator, it is a very compact device and was becoming standard for gas engine ignition.

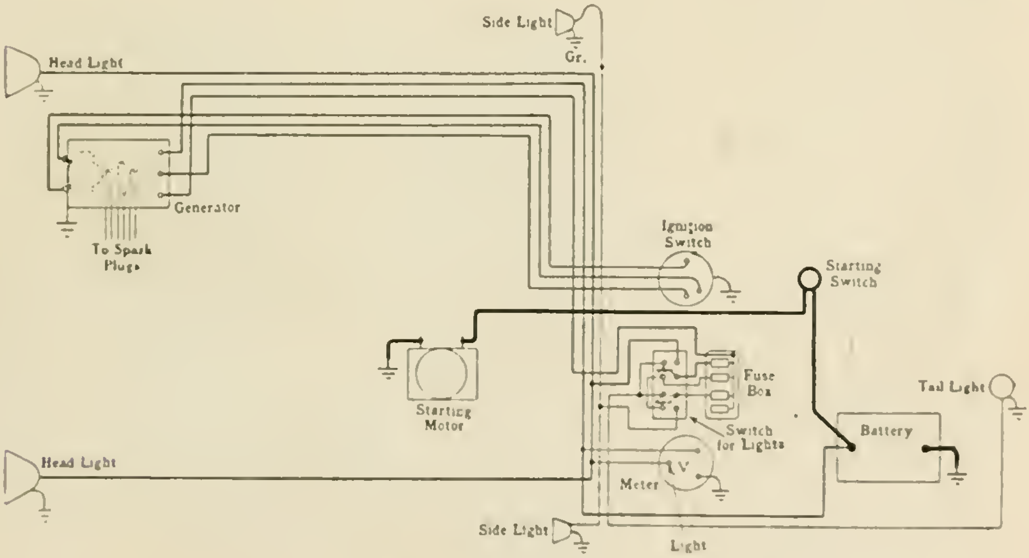

FIG. 1—TYPICAL AUTOMOBILE WIRING DIAGRAM

LIGHTING

The second important application of electricity on the automobile was for lighting purposes. Three general systems have been used; first, either an alternating or direct-current generator supplying energy direct to the lamps; second, a secondary or storage battery which was charged and from which the lamps were operated until the battery required charging again; third, a direct-current generator and storage battery operating in parallel. This last system is the most practical and is being universally adopted. The first system had the great disadvantage of poor regulation and no voltage with the engine stopped, making oil side and tail lights necessary; and the second, the disadvantages of frequent charging and the difficulty of obtaining proper charging facilities. With the generator and battery operating in parallel, the lamp load is carried by the battery at low car speed and by the generator at average and high car speeds. At the high car speed the generator charges the battery in addition to furnishing the current for the lamps and, with the lamps turned off, the generator charges the battery at all but very low car speeds. Electric lighting for automobiles really became feasible with the advent of the tungsten lamp. Lighting outfits had been designed before the introduction of metal filament lamps, but the weight, cost and power consumed were prohibitive. With the appearance of the tungsten lamp and the consequent reduction of the energy required to 30 percent of that required for carbon lamps, electric car lighting immediately became feasible. A potential of six volts, three lead cells, is being used more than any other because tungsten lamps are more rugged and usually give a better light distribution for the head lights at this voltage, and because the storage battery is ten or fifteen percent lighter per watt-hour than for higher voltages.

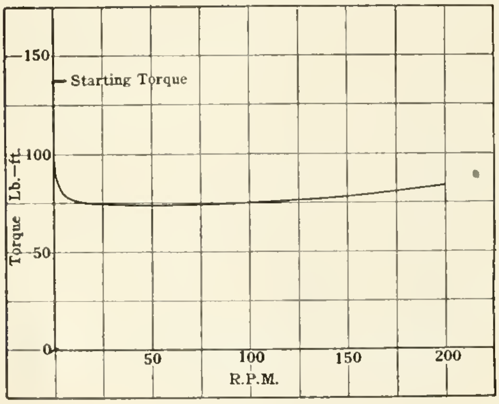

FIG. 2

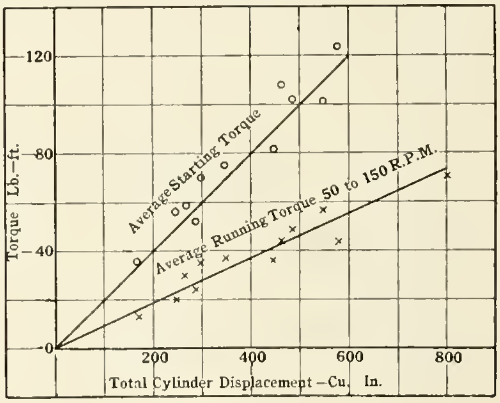

FIG. 3

Fig. 2—Variation of starting torque requirements with speed for a six-cylinder, 5 by 7 in. engine.

Fig. 3—Gas engine torque requirements for starting and running.

STARTING

Cranking a gas engine by hand is a source of great inconvenience. Many forms of air, gas and spring starters have been devised and some have been fairly successful. The need and demand for a mechanical starter has long been felt, and when a storage battery, a source of stored energy, came into use on the automobile for supplying current for the lamps, it was a natural development to use this energy for starting also. The use of the electric starter is practically a development of the last two years and its general adoption by automobile manufacturers has been so rapid that this part of the business has had a phenomenal growth.

ELECTRIC GEAR SHIFTING

The fourth and most recent application of electricity on the car occurs in the use of electro-magnets for shifting the gears. Instead of shifting the gears by a hand lever when different driving ratios are required, the gears are selected and shifted by pressing push buttons on the steering column, thereby completing the circuit through the electro-magnets, and operating the clutch. A number of automobile manufacturers have already adopted this electric gear shift as standard equipment and a number more will exhibit cars and announce its adoption at the automobile shows this coming season.

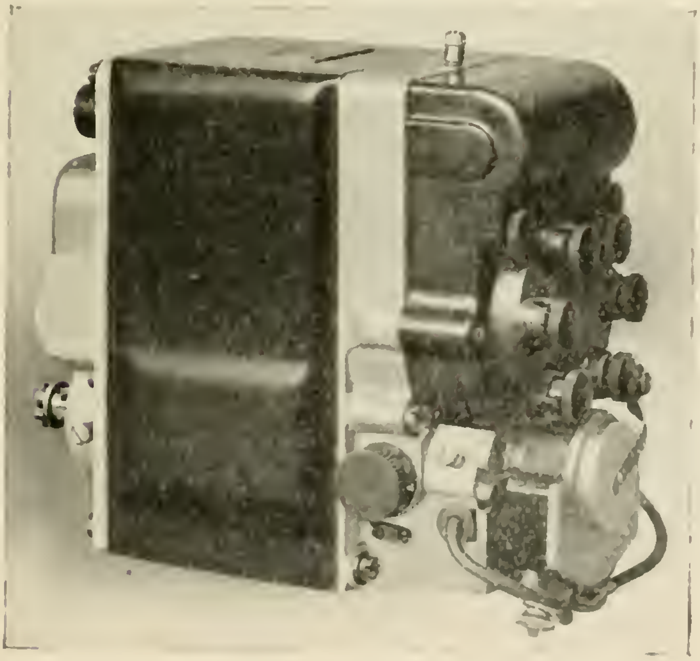

FIG. 4—LIGHTING AND IGNITION GENERATOR FOR A SIX-CYLINDER GASOLINE ENGINE

BATTERY IGNITION

With the general use of the storage battery on automobiles battery ignition is again coming to the front. This new battery ignition is different in many essentials from the old type. The storage battery is much more powerful than the dry cells which were formerly used and a much hotter and more definite spark can be obtained. The art of making storage batteries for this service has developed very rapidly and they have become reliable pieces of apparatus. With the installation of a complete electrical system on the car, frequent charging or renewing of batteries is not required. Due to recent improvements in the interrupter, a spark of approximately uniform intensity can be obtained at all speeds within the working range, and the lag in the spark at high speed which was inherent in most of the old battery systems has been compensated for.

GENERAL REQUIREMENTS

The up-to-the-minute automobile has a complete generating and distributing system; a generator to supply the current; a storage battery to take the peaks of the load; a lighting load and a power load consisting of the starting motor, ignition generator and, in some cases, other devices such as electrically-operated horn and primer. A typical car wiring diagram is shown in Fig. 1. The required performance of the electrical apparatus depends somewhat on the size of the automobile, but in general is as follows:—The ordinary lamp load is 7.5 to 8 amperes at six volts. The size and voltage of the battery depends on the system used; with the six volt systems an 80 or 100 ampere-hour battery weighing from 50 to 60 lbs. has been found to be satisfactory. Such a battery has sufficient storage capacity to average up the current requirements for the different conditions of operation. It will carry the total lamp load for eight or ten hours, will stand a continuous charging current of from 10 to 12 amperes without damage and will give a momentary starting current of from 250 to 350 amperes without injury. A good ignition device will take from one to two amperes. The ampere-hours required for starting are small; for, while the current taken is large, an average start is obtained in about two

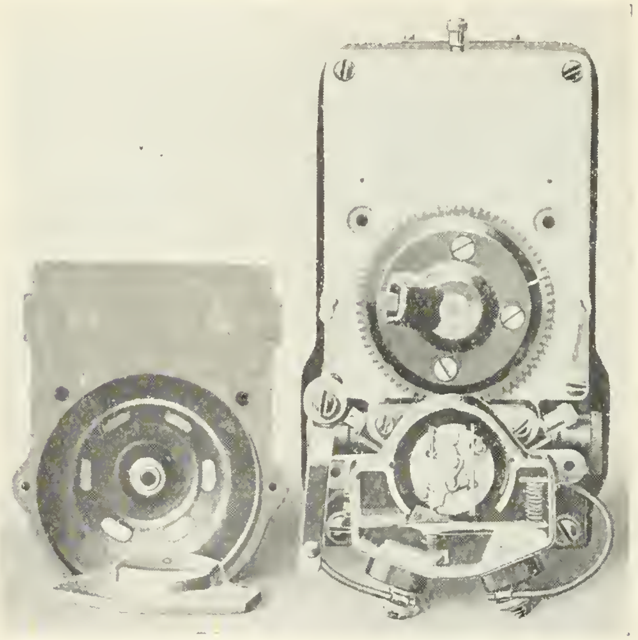

FIG. 5—DETAILS OF LIGHTING AND IGNITION GENERATOR FOR A SIX-CYLINDER ENGINE

seconds. An average current of one ampere is a liberal allowance for the starter, gear shift magnets, horn and primer. The generator should balance the lamp load at from 12 to 15 miles per hour, should begin charging the battery, with lamps turned off, at eight or ten miles per hour and should have a maximum charging current which will not injure the battery. With this performance the generator will supply the lamp load and current for ignition in average night running, will give the battery sufficient charging during day running to take care of the ignition, starting and lamp load of side and tail lamps during the time the car may be left standing at night and will give the battery sufficient overcharge to keep it in good condition and give a supply of reserve energy for unusual operating conditions. The average torque requirements of a large six cylinder gas engine at low speed are shown in Fig. 2. This torque is somewhat variable and depends not only on the size of the engine, but also on the position of the pistons, the compression and any additional friction due to cold oil, rust, etc. The true starting torque is usually from 2.5 to 3 times the torque at the cranking speed. Fig. 3 shows the average starting and cranking torque requirements of various sizes of gasoline engines. These curves are the result of actual tests and show the average requirements of new and fairly stiff engines. It is necessary to allow an additional margin over the values shown in Fig. 3 to cover conditions of starting.

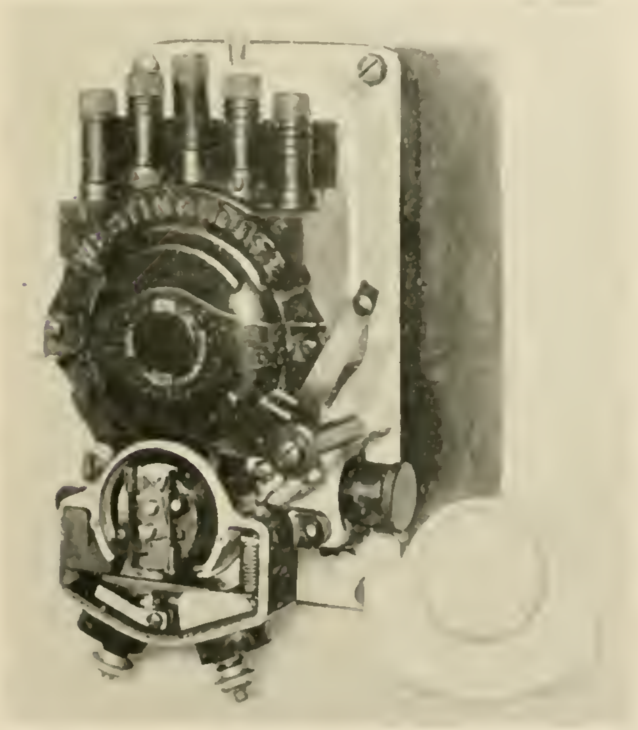

FIG. 6—DETAILS OF AN OLDER TYPE OF LIGHTING AND IGNITION GENERATOR

COMBINATIONS

There are many different systems on the market which obtain the required ignition, lighting and starting in different ways: first, the combination of ignition and lighting in one unit and starting in a separate unit; second, ignition, lighting and starting in three separate units, one of which is a magneto; third, the combination of ignition, lighting and starting in one machine; fourth, separate ignition and the combination of lighting and starting in one machine, which is a motor-generator of the direct-connected flywheel type or one which operates at from two to three times engine speed. The relative merits of these various types have been discussed at length in recent meetings of technical societies.*

DETAILED DESCRIPTION

The first and fundamental requirement of the complete system is reliability; the second, that the units be of such shape that they lend themselves to the normal car design and give a good distribution of weight; the third, that the total weight of the system shall be as low as possible in order to keep down the wear on tires, the fuel consumption per mile and the cost of the additional parts necessary to carry this dead weight. The first system previously mentioned is the one with which the writer is most familiar, using machines of the rectangular type designed especially for mounting alongside the engine under the hood. By mounting them in this manner they are readily accessible, and can easily be inspected and given any care which may be necessary. The combination of ignition and lighting in one machine gives a reduced weight as compared with a magneto and separate generator. The two functions are readily combined in one machine and this machine is easily applied to practically any gasoline engine.

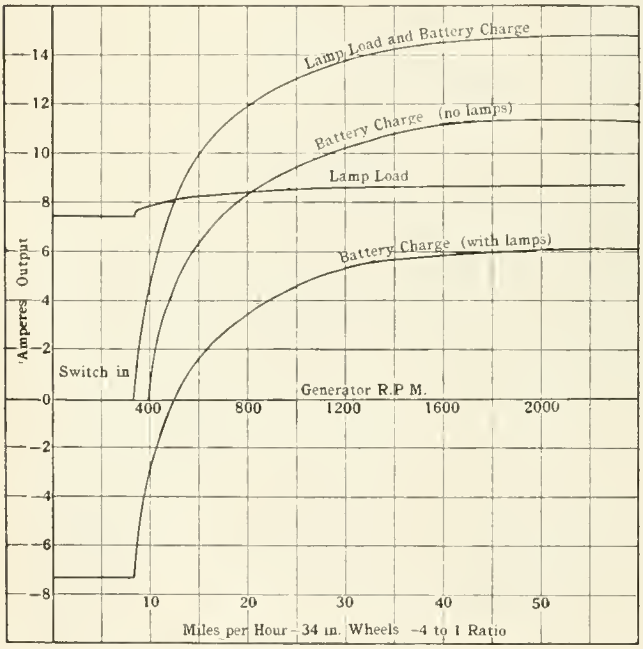

FIG. 7—PERFORMANCE CHARACTERISTICS OF A GENERATOR SUCH AS SHOWN IN FIG. 5

A lighting and ignition generator for a six cylinder engine is shown in Fig. 4, the details being shown in Fig. 5.

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*Proceeding S. A. E., May, June, October, 1913. Proceeding A. I. E. E. Nov., 1913.

It is a self-contained unit with the ignition coil moulded into the distributer plate and the condenser located in the end bracket near the interrupter where it does the most good. Fig. 6 shows the details of a lighting and ignition machine of an older type with separate coil and condenser. Fig. 7 shows the performance of a generator which weighs about 35 lbs. It is of the differential series type with automatic cut-out switch. Connections are made so that the current for the lamps does not pass through the series field. This gives the generator a greatly increased output when the lamps are turned on and takes care of the car which is operated a great deal at night and very little in the day time.

The ignition parts of the lighting and ignition generator add only about five pounds to the weight of the lighting generator. As a magneto weighs anywhere from 15 to 25 pounds this represents a clear gain of approximately 15 pounds. The interrupter, as shown in Fig. 5, is known as the beam type and consists of a stiff member, a spiral spring, fibre bearing, platinum contacts and bumper blocks. In place of an ordinary cam as used in a magneto, a combination of weights and springs is used. The object of this arrangement is to give an approximately constant time for the current to build up in the primary of the ignition coil. Fig. 8 shows the rise of current in the primary of the ignition coil when operating on the six volt battery. In order to get a good hot spark, a time interval of about 0.003 second must be allowed for the current to build up, but the contacts must not be allowed to remain together too long at low speed on account of the large current taken from the storage battery. An interval of from 0.003 to 0.015 second represents the commercial limits for the time of building up current in the primary and within these limits approximately uniform spark intensity is

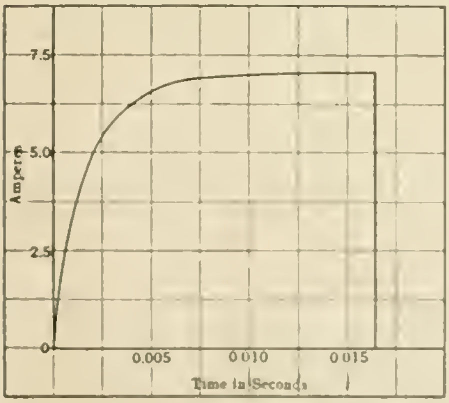

FIG. 8—CURRENT RISE IN PRIMARY OF IGNITION COIL

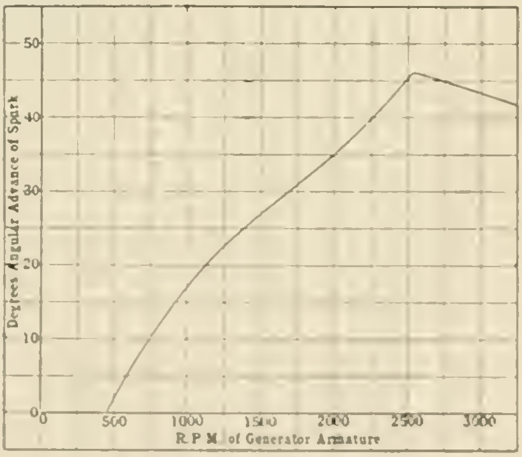

FIG. 9—AUTOMATIC SPARK ADVANCE WITH INCREASE IN SPEED

obtained. The weights, by giving small arc of contact at slow speed and a very much increased arc of contact at high speed, keep the actual time of contact within the limits previously mentioned. The centrifugal weights in addition to their function of giving uniform spark intensity, advance the spark as the speed increases. Fig. 9 shows the degrees advance of the spark in terms of generator speed. It is not possible, however, with this arrangement to do away with hand control of the spark. The hand control is necessary to take care of the general conditions which affect the timing of the spark and the automatic feature takes care of changes in speed. The current in a high tension spark obtained from this battery ignition outfit is shown in Fig. 10, and the current in a high tension spark from a standard high tension magneto is shown in Fig. 11. Comparing these two sparks, the currents at the first instant, or in other words, the spark intensity at the time of firing, is found to be approximately the same for both. With the battery ignition this same spark intensity is maintained at all speeds, while with the magneto it decreases at low speed and increases somewhat at very high speed. A spark intensity as shown in Fig. 10 and 11 is amply sufficient and any increase only tends to burn the points of the spark plugs, whereas any material decrease at low speed means uncertain operation.

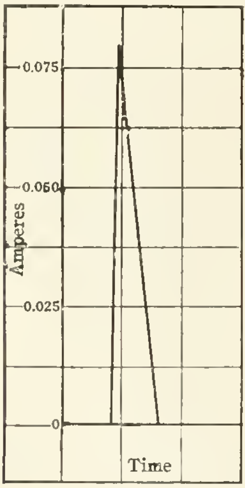

FIG. 10

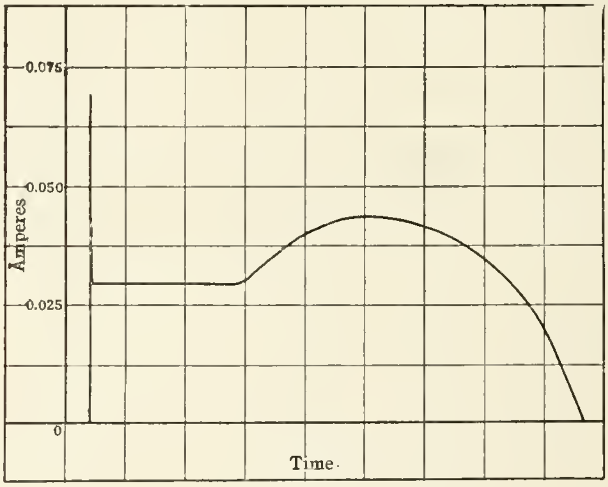

FIG. 11

Fig 10—Oscillograph of the high tension spark of an ignition generator.

Fig. 11—Oscillograph of the high tension spark of a standard magneto.

By using a separate starting motor advantage can be taken of the light weight and good performance of a high-speed machine, such as is shown in Fig. 12. These motors are made in half and three-quarter horse-power sizes at approximately 2 500 r.p.m. when operating on the battery voltage, which varies from 5.2 to 5.5 volts, depending on the condition of the battery and the resistance of the car wiring. The machines are of a rectangular type, designed for mounting under the hood alongside of the engine and weigh 18 and 23 pounds in the half and three-quarter horse-power sizes. The rating of a motor is given at the normal cranking speed of the engine to which it will be applied. In other words, if the engine is started up without gasoline it will be turned over by the starting motor at this normal cranking speed and, in so doing, the starting motor will develop its rated horse-power. Fig. 13 shows the starting torque of the gas engine and the torque developed by the starting motor at the engine shaft. Where the curve of the torque developd by the starting motor crosses the curve of the torque required by the gas engine the balancing speed or cranking speed is obtained. Applications are usually made so that with stiff engines or with very cold engines a cranking speed will be obtained of at least 80 r.p.m. for a four cylinder and 60 r.p.m. for a six cylinder engine. Under normal conditions of operation a much higher cranking speed will be obtained, ranging from 100 to 125 r.p.m. for the four cylinder and 75 to 100 r.p.m. for the six cylinder engines. Figs. 14 and 15 show the details of a starting motor, including the gears in the gear box. The same starting motor can be used with a number of different combinations of gears. The one shown is a planetary gear box giving a ratio 9.5 to 1.

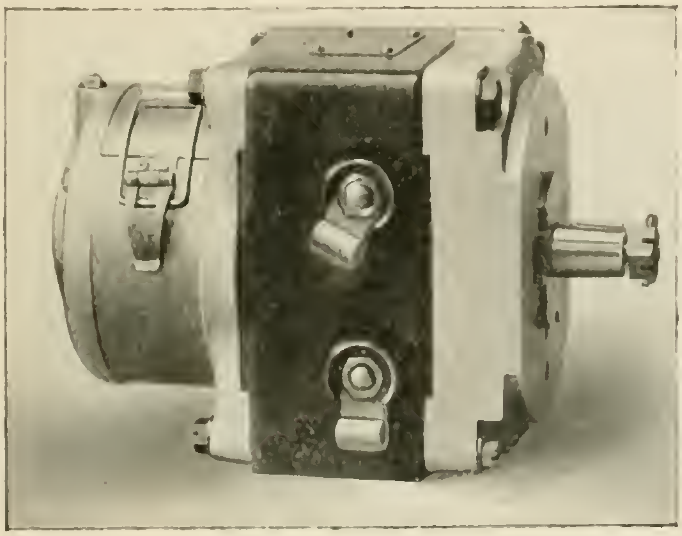

FIG. 12—A HIGH-SPEED GAS ENGINE STARTING MOTOR

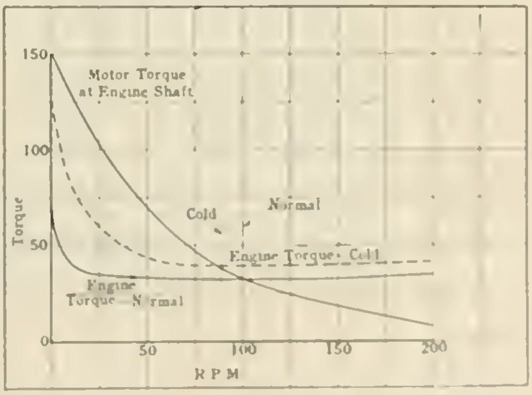

FIG. 13—VARIATION OF MOTOR STARTING TORQUE WITH R.P.M., AND THE CORRESPONDING TORQUE REQUIREMENTS OF THE GAS ENGINE

A typical application of front end drive for starting is shown in Fig. 16. A chain drive is used from the starting motor gear box to the engine shaft. With a ratio of 9.5 in the gear box and approximately 2.5 in the chain a total ratio of 23.5 to 1 is obtained. On this particular application this gave a cranking speed of approximately 110 r.p.m. when the engine was reasonably stiff. An over-running clutch of the roller type is used on the engine shaft so that the starting motor can drive the gasoline engine, but the engine cannot drive the starting motor. With this arrangement the chain is in operation only during starting.

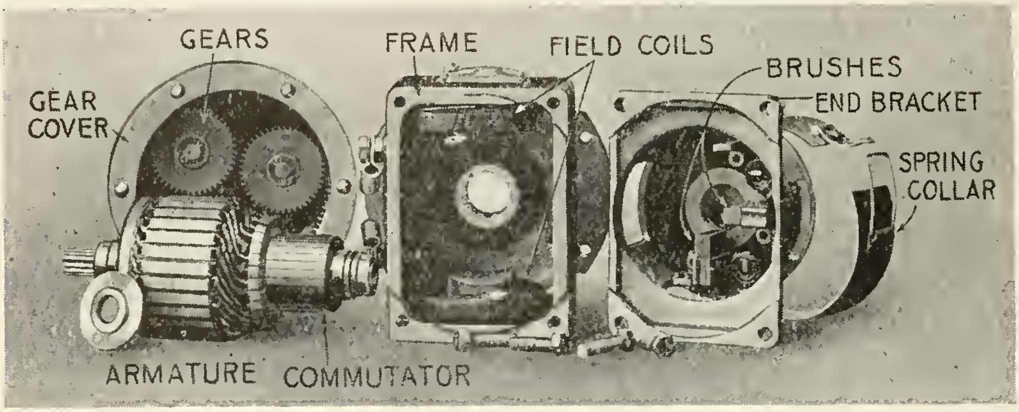

FIG. 14—DETAILS OF STARTING MOTOR

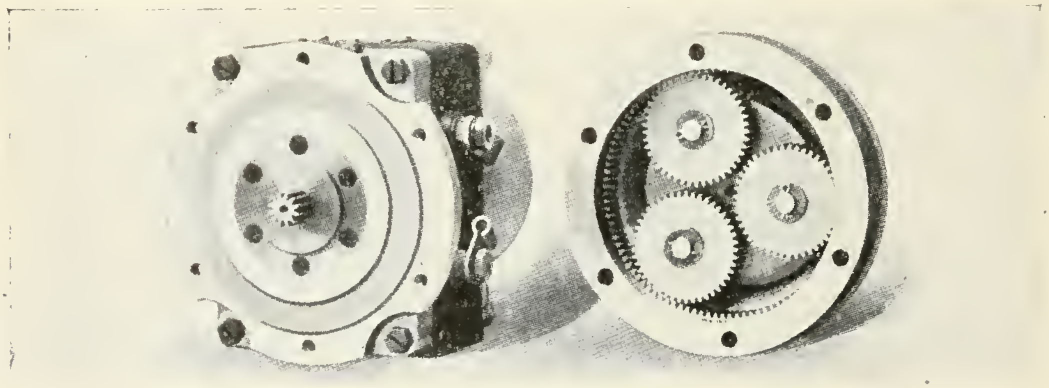

FIG. 15—DETAILS OF STARTING MOTOR

A typical flywheel application on an engine with an enclosed flywheel is shown in Fig. 17. In this particular installation a lighting generator and magneto were used. A gear ratio of between 15 and 30 to 1 is obtained by means of double reduction spur gears. The large gear can be made by cutting teeth directly into the flywheel or by bolting a separate gear to the rim of the flywheel. A reduction of approximately 8 to 1 can be obtained in the flywheel proper and the additional reduction must be obtained in the back gear. Applications have been made in which the pinion of the back reduction gear is shifted into the flywheel by an electro-magnet. This makes a very neat application and one which can be interlocked with the generator so that the starting motor operation can only be obtained at low engine speed. There is thus no danger of damaging the starting mechanism by accidently trying to throw the pinions into mesh when the gasoline engine is operating at high speed.

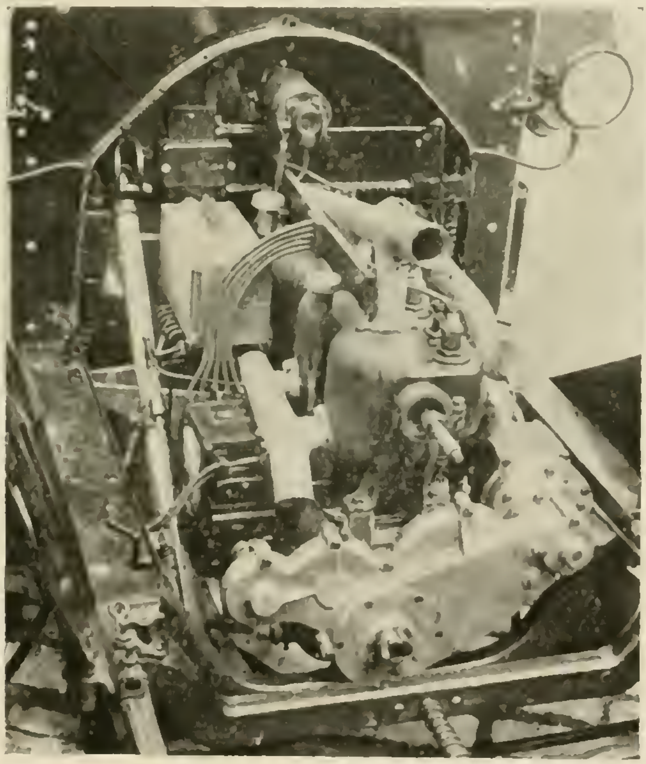

FIG. 16—APPLICATION OF FRONT-END DRIVE FOR STARTING

CONCLUSION

The development of the present electrical equipment for automobiles has been very rapid. Additional improvements and changes may be expected in the next two years, and there probably will be a tendency to adopt one or two systems as standard. This is especially true because a number of automobile companies buy practically all parts from accessory manufacturers, and merely assemble the parts to form a car. With this scheme of building cars it is highly important to have standard equipment which can be used on all makes of engines and all arrangements of assembly. The development will be in the line of increased reliability, reduced cost and improved methods of applying or assembling the electrical equipment on the automobile. A number of applications at present on the market are quite apparently make-shifts and will be undoubtedly changed when the automobile manufacturers bring out their new models. In the case of many four cylinder engines, three units cannot readily be placed under the hood of the engine. It is very difficult to foresee what the ultimate application is likely to be, but it certainly will not consist of more than two units. This probably means a combination of ignition and lighting in one unit with separate starting motor.

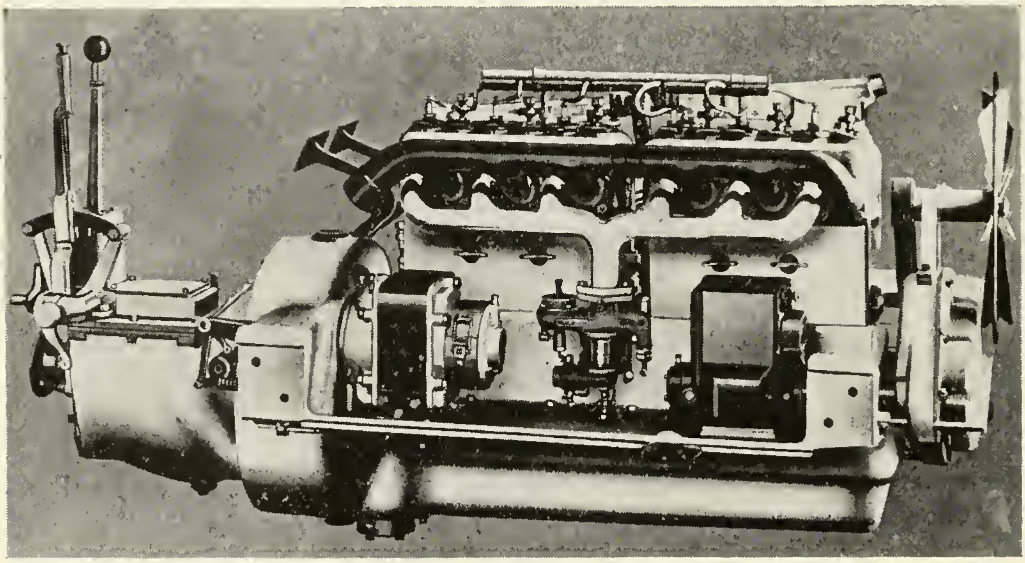

FIG. 17—APPLICATION OF FLYWHEEL DRIVE FOR STARTING

ARTIFICIAL RESUSCITATION*

CHAS. A. LAUFFER, M.D.

Medical Director, Relief Department, Westinghouse Electric & Mfg. Company

VARIOUS methods of restoring life in persons apparently dead have been practiced from time immemorial. Of these the Sylvester-Laborde was largely in vogue, until superseded by the Schaeffer, or prone pressure method. By spirometer methods of accurate determination, the old Sylvester-Laborde method is reported to have an efficiency of 175 c. c. of air expelled, against 520 c. c. by the Schaeffer method.

In addition to the higher efficiency of the Schaeffer method, it utilizes the diaphragm, which is the chief muscle of respiration, whereas the old, laborious Sylvester method expended the chief time and energy on the pectoral and intercostal muscles, which physiologists have always regarded as accessory muscles of respiration. The normal lungs are unattached to the chest walls; only their blood vessels and the bronchi give them support. When empty, the lungs are partly collapsed, and when filled with air they are expanded to occupy the cavities designed for them. Using the lungs of a cat in the familiar bell jar experiment, and employing a sheet of rubber to represent the diaphragm, it is self-evident that the natural mode of inflating and emptying the lungs is by the activity of the diaphragm. The diaphragm is an arched muscular partition. Its convex surface is the floor of the chest; its concave surface is the roof of the abdomen. It is as necessary to life as the heart; the continuous rhythmic contractions of both muscles are necessary to continual life. A man can fast forty days if water is plentifully supplied him. He can be deprived of sleep for eight days and nights and may recover, but if he is deprived of air for three minutes he is liable to perish.

The conditions under which the action of the diaphragm will be paralyzed, thereby depriving a man of air are:—

1—*Electric Shock*—By its action on the nervous system, the passage of an electric current may arrest the action of the diaphragm.

2—*Asphyxiation*—There are forty or more non-respirable gases which, upon entering the lungs, paralyze the respiratory center in the brain (medulla). Exclusion of air, as in a closed vault or in drowning, produces asphyxia, due to the lack of oxygen and the retention of carbon-dioxide. Certain drugs, as opium, in a similar manner arrest the action of the diaphragm. Chloroform and ether may act in this manner.

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*Based on a paper read before the Eastern New York section of the National Electric Light Association, September 15, 1913.

3—*Traumatic Shock*—A blow on the head, jaw, or neck, or over the solar plexus, will sometimes paralyze the diaphragm. A man who gets such a knock-out blow must be made to breathe until his disturbed nerve centers recover their normal functions.

The time to prepare for such calamities is right now. Every man should know how to give artificial respiration. Suspended animation requires instant relief, and the man who fails to qualify himself, and who does not know how to resuscitate a comrade when the emergency arises, is morally guilty of manslaughter.

If the victim of electric shock, or drowning, or of suffocation by gases, is allowed to be without air until the doctor arrives, some inconsiderate person who himself has neglected to practice up on artificial respiration, will complacently attribute the death to the tardiness in the arrival of the doctor. Another individual, who has failed to qualify himself in artificial respiration, may attribute the loss of life in electric shock to the high voltage, or other unfavorable factors; he may endeavor to exonerate himself on the ground, that even if he had understood the method, the man was already dead, and efforts at resuscitation would have been futile. Such sophistry is but a cloak for indifference and ignorance. Every man who requires artificial respiration should be given a chance. It is as much your business as it is the doctor's to be prepared in anticipation of any such emergency, and to be able to administer artificial respiration. No man of average intelligence and ordinary conscience should be exempted from practicing the method.

RECOVERY A POSSIBILITY

Men have received 8 000 and 10 000 volts—we personally know of one who received 11 000 volts—and recovered. Arc and static discharges from 240 000 volt conductors, and even higher voltages, are not necessarily fatal, if artificial respiration is resorted to at once, as the following actual instances will show:—

Case A—During July, 1913, a patient received 8 000 volts. He was unable to release himself from a live wire he had inadvertantly touched, and which was fastened to a switchboard. He had failed to trace its source, but started to unscrew the connection; his right hand touched the screw, his left hand held the bare wire, while the current went through his body. The left hand folded over the right breast, and in falling his right forearm and back came in contact with iron piping. He was badly burned in five places.

The comrade nearest him who saw him drop, took four steps to pick up a piece of wood, ran back the four steps and knocked the line out of his hand. The duration of the dangerous contact exceeded fifteen seconds.

It required fifteen minutes of rhythmic effort at artificial respiration to get him back to normal breathing. For a time he breathed as though every breath would be his last, his diaphragm being in tetanic contraction, but by increasing the elevation of the diaphragm at the rate of twelve times a minute, by the prone pressure method, this spasmodic type of respiration subsided, and normal breathing was restored. Mr. E. V. Saunders rescued him from the line, and he, together with Mr. C. W. Diehl have the honor of this resuscitation.

Case B—This accident occurred five years ago. The patient opened a live circuit and fell against a steel hose, receiving 10 000 volts, and the contact was of several seconds duration. He lost two fingers and carries ugly scars on his palm, wrist and back. His case presented a severe complication, edema of the lungs; fully two pints of bloodstained serum was expectorated, but he reacted to drugs and cracked ice, and his burns healed happily.

The honor of this rescue and resuscitation belongs to Mr. F. S. Peterkin, a man who has resuscitated six men without a failure. One hundred percent of success is noble achievement; all of his cases were at high voltage, and of a serious type. Why this man's uninterrupted success? He gets busy at once, for every second is an hour when the action of a man's diaphragm is paralyzed. He works continuously at the artificial respiration; he does not stop to theorize about the fibrillating heart, or the probability of hemorrhage in the brain and spinal cord. A victim of electric shock, and other conditions requiring resuscitation, needs instant assistance in the way of artificial respiration; few persons are killed outright by electricity.

Case C—This man received 11 000 volts, yet was successfully resuscitated. His palms were so deeply burned that both hands were subsequently amputated.

Cases are on record, moreover, where patients were declared dead by physicians, yet by the prone pressure method of artificial respiration have been resuscitated. But because prone pressure has no apparatus to sell, it has no publicity department and the general public is too little informed of these successes. There will always be need of manual methods, yet some of the mechanical devices should probably be endorsed. But until all cases are honestly reported, manual methods will not receive due publicity; the commercial interests back of the mechanical devices boost their apparatus, and disparage manual methods, notwithstanding the fact that manual methods are necessary to keep the patient alive until the apparatus can be brought to the scene. It is then customary to give such apparatus the entire credit for the resuscitation.

RULES FOR THE PRONE PRESSURE METHOD

1—*The Position of the Patient*—The patient is laid flat on his stomach, face turned to one side, so that the mouth and nose do not touch the ground. His arms are drawn away from his body, or extended above his head. The mouth is cleaned of mucus, blood, serum, tobacco, chewing gum, false teeth or any other obstruction, by a stroke of the finger. This prone position causes the tongue to fall forward of its own weight, as well as facilitates the removal of liquids from the mouth and air passages by gravity. It is this fact that makes it possible for one man, alone and unassisted to save the life of a comrade in drowning, electric shock, or other condition requiring artificial respiration.

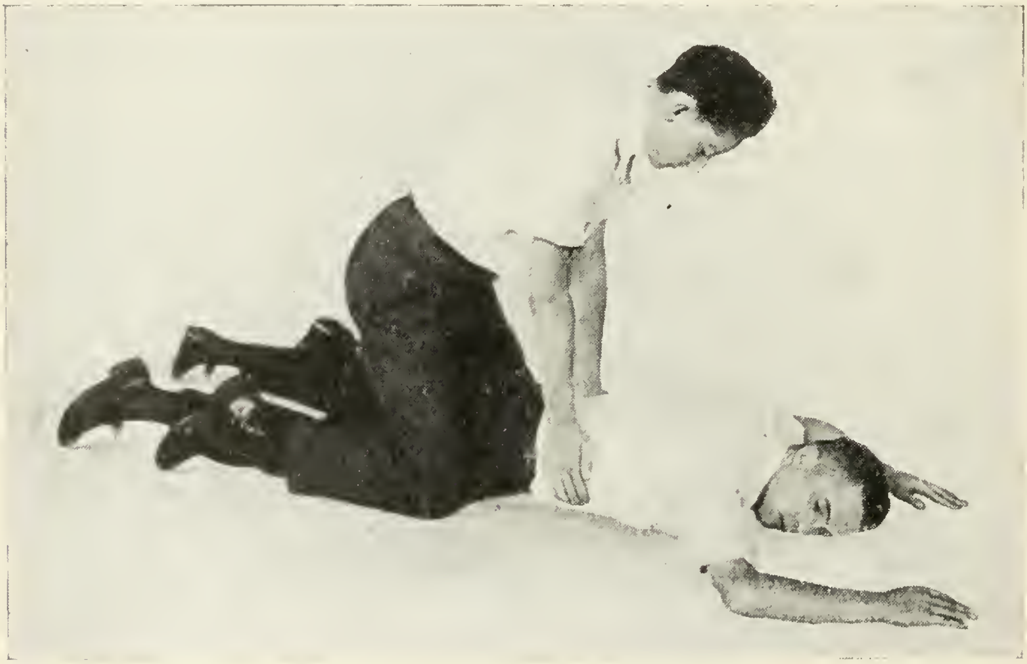

FIG. 1—CORRECT POSITION FOR APPLICATION OF PRONE PRESSURE METHOD OF ARTIFICIAL RESPIRATION

2—*The Posture of the Operator*—The operator kneels, straddling the patient's thighs, or kneels by either side of the thighs, facing the patient's head. The operator's hands are placed on the outer ends of the patient's lowest ribs; the fingers curl around under the body, and are out of the sight of the operator. Care is observed to keep the hands away from the spine, and to avoid pressure on the pelvis.

3—*The Mode of Operation*—The operator's thumbs are rotated outwards, which assists him in holding his arms straight; he does not use his arm muscles, but his body weight is brought from his shoulders, by bringing his body and shoulders forward. This weight is gradually increased (there is no sudden thrust), until at the end of three seconds of vertical pressure upon the lowest ribs of the patient, the force exerted is felt to have compressed the parts, then the weight is suddenly removed. When the pressure is thus exerted on the lowest ribs, the organs under the diaphragm (the liver, stomach, spleen, kidneys, etc.) drive up the diaphragm; when the hands are removed, or the pressure remitted, the displaced organs drop back to their normal relations. When the diaphragm is thus forced to rise, the lungs are emptied. When it descends, a partial vacuum exists, and the lungs are filled by atmospheric pressure. The lungs are thus passive, like in normal breathing. Hence, by the prone pressure method, there is no possibility of lacerating lung tissue, such as is liable to occur when mechanical apparatus of the bellows type is employed

4—*Rate Per Minute and Duration of Operation*—The rate of operation should be about twelve times a minute. The lungs should be thoroughly emptied by three seconds of vertical pressure, in the manner described; then the hands are removed, and the refilling of the lungs takes care of itself. Pressure and release of pressure—one complete respiration—occupies about five seconds. This rate can be approximated by the operator following his own deep regular respiration, if he is alone; or by counting, or he can use his watch. If comrades are present, he can be guided by them.

Such efforts are usually successful within twenty-five minutes, but should be continued indefinitely, without interruption for any cause. One hour, even two hours or more, may be required to bring the patient to consciousness.

5—*Supplemental Assistance*—While the artificial respiration is being carried on, a second party should clear the mouth of all foreign material, then hold continuously a cloth saturated with aromatic spirits of ammonia near the nose. While this is being attended to, a third party summons a doctor. No liquids dare be given by the mouth while the patient is unconscious. On the arrival of the doctor, he can stimulate the heart of the patient with such drugs as atropin and strychnin, and can direct the supplying of external heat, if there is collapse, or the weather is cold; and he can direct the infliction of such pain as is deemed requisite, such as pulling the patient's hair, pounding with a board, slapping, rubbing, stretching the sphincter ani muscle, pulling the tongue.

In conclusion, as a manual method, the prone pressure or Schaeffer method, holds the position of primacy. It has been the writer's good fortune to instruct over 2 000 persons in this method. Those who have had occasion to employ it, believe firmly in its efficiency. We have used it since 1909, and regret only that Prof. Schaeffer delayed until 1908 the presentation of the facts of his method before the American Medical Association.

HERO MEDAL RECOMMENDED

The National Electric Light Association is to be congratulated for officially adopting this method in 1912. The writer wishes to suggest also the presentation of bronze medals to the men who resuscitate comrades from electric shock. Such a medal could be worn on a watch fob, or otherwise. It would be inexpensive to the Association, the intrinsic value of the badge being insignificant in comparison with the appreciation of every recipient of such a gift. It would be a badge of honorable distinction, and the distribution of such awards would doubtless contribute more to the propaganda of right methods of artificial respiration than it is possible for those of us to attain, who use our pens, our voices and our arms, in describing and in demonstrating the prone pressure method.

Investigations would be instituted to see that claims are bona fide in each case. Hence, such a custom, if introduced, would form a basis for collecting data on these cases. Cases of neglect and failure could be recorded, and successes achieved under every method of artificial respiration would go on record, and the results could be tabulated. By such compilation of the universal progress of world events in this field, successful experience will stimulate others to like achievements.

The general welfare requires that we establish such a clearing house, possibly under the joint auspices of all the electrical societies. None of us know enough about right methods of artificial respiration; the best experience should be universalized. The National Electric Light Association has taken a laudable initiative in this educational movement. An advance step would be the accumulation of records of cases of success and failure with detailed information on each case, along with some arrangement for the bestowal of suitable medals on the heroes in the electrical service.

SOME ENGINEERING REMINISCENCES

S. TROOD

This article is based on a talk delivered before the Progress Club of Pittsburgh. The author was born and educated in Russia, but for a number of years has lived in the United States, and is a consulting inventor of wide experience.—(Ed.)

A MAN with an inventive frame of mind who visits a large manufacturing concern for the first time is likely to come to the conclusion that a considerable saving of money could be accomplished almost everywhere, and that the management must either be blind or else unable to direct or instruct. These conclusions, however, are not usually warranted. An increase in the efficiency of the workmen does not always mean increased profits, nor do improvements in working conditions or in machinery necessarily mean increased efficiency. In many cases such improvements, when reduced to practice, do not accomplish the expected results. Sometimes the desired results are secured, but they are so dearly paid for that they are hardly justified. The statement "paid for" means not only in money, but also in the chances a large concern takes when undertaking changes in a gradually developed industry that the confidence of its employes will be lost, shop routine will be upset, or that a loss of prestige may be incurred.

Continual improvement, betterment and increased efficiency are necessary for the growth of any manufacturing concern. But before any improvement is introduced it should be carefully analyzed. An investigation should be made to find out whether the scheme was ever introduced or undertaken in the past, and if so with what result. If no record is found a conservative attitude should be taken and a study made to estimate what that improvement will mean, both directly and indirectly. Will the changes required by the improvement directly effect only the immediate surroundings, or will they indirectly effect a considerable part of the plant? Upon studying the situation, it is frequently found that the actual problem to be solved is not that which has presented itself, but that, upon taking into consideration all the conditions, an entirely different problem must be taken up and investigated. Thus a demand for higher temperatures may, instead of requiring the addition of more heat, resolve itself merely into a better utilization of the heat which is already being supplied.

Why is it then that the man with the inventive frame of mind sees all those opportunities for apparent improvement, which to him are so obvious? He is influenced only by his logical imagination. That it is only logical imagination and does not include a complete analysis, follows from the fact that not all suggestions bring expected results. Having introduced the term "logical imagination," it will be well to explain what is meant by this term. Everyone is subject, in a greater or less degree, to imagination, but only when the imagination is held within the bounds of reason may it be called logical. Imagination, however, even logical imagination, has no place in the field of improvement, betterment or efficiency unless it is limited by practical common sense. And only those suggestions of improvements, betterment projects and attempts at efficiency, which are the product of the thought of the man who employes common sense are commonly successful. A few examples taken at random from the writer's past experiences are more fully illustrative of this point.

As a young engineer, entering a postgraduate course in technology, I was given a certain list of questions. One of these was, "What should be done with a broken thermometer?" At first I was surprised and was considering the connection of the laws of Boyle and Charles and Marriott to this problem, when the suggestion came all at once, "What is the use of it all." Why consider the repair of an article that had such a relatively small first cost that a new one could be purchased for less than it would take to repair it." The solution of this problem required no knowledge of higher mathematics or physics, but simply the use of a little common sense My answer was, "Throw it out the window," and it was partially due to this particular answer that I was admitted to the university, although some of the board of examiners were shocked.

After graduation I was of such importance in my own mind that I thought I carried the world on my shoulders. I was filled with the importance of my knowledge, and it was not until I came in contact with practical men and practical work that I found of what actual importance my knowledge was.

When doing some surveying on an excavation at this time, I was very careful that all readings should be very accurate even to a small fraction of an inch, and was considerably taken back when a common instrument carrier, who had no education but had been at this work for several years, told me that I was allowing the contractor too much. Soon after it was found that I was making the mistake of taking too many high points and thus giving too large an average. It was after this that I felt as if a great burden had fallen off my shoulders and I was relieved from the weight of my engineering importance. For many years after that I remembered that lesson and Jim, the instrument carrier.

Some time after that, having had considerable practical experience, I invented a new method of propelling ships, and was under the impression at that time that it would revolutionize navigation. I spent considerable time in study and development of the idea, keeping everything a secret. I not only could not trust my friends with the secret, but could not select a patent attorney to be trusted. After long deliberation, I went to Hamburg to one of the largest ship building concerns (I am ashamed even today of the big fuss I made before I disclosed my secret to them). One of the heads of the firm, who had a fine military bearing, called for Fisher's English patents, and in that I was shown a duplicate of my idea to the smallest details. I was shocked, not because I lost, but because I was quite severely reprimanded by this man who said: "Young man, you may be a great inventor; you may be greater than Fisher; but if you had spent an insignificant sum to consult a patent lawyer, you would have known then all you know now, and would not have bothered us with all of your correspondence to secure this appointment." Although it was a disappointment, yet it was a great lesson in common sense and from that time I never introduced an invention or idea without first consulting a good patent attorney or making a thorough search.

Several years later, when in charge of a small section of railroad in South Russia, I received telegraphic orders from my immediate superior, on one occasion, to see that there was ample clearance of a certain amount at all bridges to pass a special train for the Czar. I was also to report the cost of the temporary changes, if any. In looking over the section, we found that five of the road bridges would have to be raised six inches. Unlike those in America, these roads were great single thoroughfares for caravans, and at this time they were crowded by the movement of grain to market. It was also the time for a large country fair, and the roads were in constant use. To raise the bridges temporarily for about a week, would have caused much hardship and inconvenience. At first it seemed there was no alternative, but to proceed with the orders, and the work was about to begin, when I thought that it must be some small part of the Czar's train which required this extra clearance, and perhaps this might be altered. In order to save time, I went over my superior and telegraphed the chief in charge, asking if this were not true, and received word direct from him to stop all alterations at once. A later telegram explained that it was the high coat of arms on the new imperial car which caused the extra clearance, and alterations would be made in this, rather than in the bridges, to provide the necessary clearance. This use of a little common sense not only cost the position of the man who reported the necessary clearance without explanation, but also cost me mine. I had the satisfaction, however, of knowing that the bridges were not raised.

At another time a city was supplied with water from a pumping station surrounded by low marshy land, which in the spring was covered by the river. At this time the water main to the city was broken accidentally by the anchor of a passing barge. The problem was to locate and fix the break. The location was hard to determine, since the water was seven feet deep and the length of main under water was several hundred yards. After desperate efforts by the water engineers to locate the break, the suggestion was made to pump air through the mains from both ends, and from bubbles rising to the surface, the extent and location of the break could be determined. After locating the trouble by this method, four old barges were sunk around the spot and by means of sacks of straw and dirt, the water was kept back and the pool drained. It was then a very simple matter to repair the main.

Many more examples of a similar character of experience abroad in the application of common sense to everyday engineering could be given, but we will pass over a considerable period and give some examples from my work in this country.

I was over thirty years of age when I reached New York, and immediately on landing began looking for an occupation, where my knowledge and experience would be advantageous. I was so very much handicapped by not speaking English that almost the only thing left was hard manual labor. Before I resorted to this, however, I had my first experience with American common sense. Having a knowledge of the elements of chemistry and being an amateur photographer, I tried to sell a new method of photo-engraving to an American lithograph company. When I met one of their managers he said, "I will show you how we are doing that work, and if your method is superior to ours, we will talk business." I was very much surprised, for their product was practically as good as mine. By using another chemical, I was able to get a little better results, and since that was such a small part of the operation, I disclosed it to him. In leaving, I asked him why he would trust me, a perfect stranger, with such important information. He said, "Our protection is our thirteen-story factory and our two million dollar working capital and our unlimited credit." This was a new kind of common sense to me, and so different from anything that I knew before, that I resorted to common labor until I should become better acquainted with American methods. For several years I was a laborer working from the bottom up, and during this period I found that common sense was the only substitute for skill, knack or training.

When I had learned to speak English, and had become a foreman for a large electric concern, I was sent to a job that was already under way but was giving much trouble. No one was satisfied. For two days I studied conditions and noticed that the trouble was of a psychological character. The foreman preceding had had no end of trouble. Men who were adapted for scaffold work, were doing fitting, and strong men trained for pipe roughing were doing moulding work, and vice versa. I gradually rearranged the men to give them work to which they were accustomed. The trouble left as if by magic and time, money and material were saved. For this work I was promoted by the concern, and at the same time I was called to answer to charges by the union. The charges were that the job was finished in too short a time. The charges were dismissed when it was proved to them, by the workmen themselves, that none of them worked any harder than customary and even easier than under the previous foreman. It was further proved that by removing all elements of uncertainty in the work, and always having suitable material on hand, the work was finished much quicker and yet without overworking the men.

This example illustrates how common sense in the direction and supervision of men will accomplish remarkable results. This kind of common sense applies especially where the price of labor is an important factor in the total cost. It is hoped that the preceding observations, while taken from the author's personal experience, will be of value to others by causing them to take into account conditions which, while not necessarily obvious, may have an important bearing on the general result.

SHOP TESTING OF ELECTRICAL APPARATUS—XII

ALTERNATING-CURRENT GENERATORS AND SYNCHRONOUS MOTORS (*Cont.*)

EFFICIENCY BY LOSSES

THE DETERMINATION of efficiency by actual load test to find the relation between out-put and in-put is not practicable on machines of any size, so that the method of efficiency by losses is usually employed. This method is based on the results of the tests already described and is determined as follows at no-load and each quarter-load up to 25 percent over-load:—

Let E = Normal terminal volts.
I = Amperes per phase.
i = Field amperes at load I.
R = Resistance per phase as measured across terminals hot or at 60 degrees C.
r = Field resistance hot or at 60 degrees C.
Then (1) = Total ohmic drop in the armature, e.
(2) = Total induced volts, $E+e$ for generators, $E—e$ for motors.
(3) = Core loss at the total induced voltage (2) obtained from the core-loss curve.
(4) = Field copper loss i^2r.
(5) = Armature copper loss.
(6) = Friction and windage of machine, (if included).*
Total losses = (3) + (4) + (5) + (6).
Output = $E \times I$ (total) × power-factor.
Input = Output + total losses.
Efficiency = Output ÷ Input.

The input and output of synchronous motors are always given in terms of horse-power. The values of I to be used in the foregoing equation may be determined from Table I. A complete calculation for the determination of efficiency by the above method is given in Table II.

TEMPERATURE TESTS

With normal load or its equivalent applied to the machine, the temperature test must be continued until all parts have reached a constant temperature unless the machine has an intermittent rating. The run should be continued for at least one hour after the field voltage and the temperature shown by thermometers have become constant.† The time required for a total run will vary from six to twelve hours, according to the type of machine.

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*In synchronous machines built without shaft or bearings, friction and windage is not included in the calculation of efficiency, being charged to the engine or other prime mover of which it is considered to be a part.

†For instructions for placing thermometers in the temperature test, see the JOURNAL for January, 1913, page 68.

Over-load temperature tests must be started with the machine at the normal load temperature unless the guarantees specify otherwise. The machine is run on the normal load until the temperatures and field voltage are constant. Then, without shutting down, the load is increased to the required amount as quickly as possible. Care must be taken that the over-load tests are run for the exact length of time specified, since a difference of even a few minutes in the running time may make a difference of several degrees in the final temperature. Readings are taken of terminal volts, terminal amperes and watts in each phase and field volts, field amperes, speed and temperatures. A complete set of readings is then taken every hour during a continuous run, and every half-hour on the over-load or other temperature tests of less than two hours duration. The load and voltage must be held at the required values during the entire temperature test.

TABLE I—DEFINITION OF TERMS FOR DIFFERENT NUMBERS OF PHASES

Phases and Connections	Ohmic Drop (e)	Armature Copper Loss	Total Armature Current
Single-phase	IR	I^2R	I
2-phase	IR	$2\ I^2R$	2 I
3-phase, star or delta	0.866 IR	$1.5\ I^2R$	1.73 I
6-phase, closed winding, diametrical connection	1.333 IR	$4\ I^2R$	3 I
6-phase, open winding, diametrical connection	IR	$3\ I^2R$	3 I
6-phase, closed winding, double delta connection	1.333 IR	$4.5\ I^2R$	3.465 I
6-phase, open winding, double delta connection	0.866 IR	$3\ I^2R$	3.465 I

TABLE II—EFFICIENCY BY LOSSES

Load percent	0	25	50	75	100	125
Line amp. per terminal	0	49	98	147	196	245
Field amp.	77	81.5	86.5	94	101.5	112
Terminal volts	6300	6300	6300	6300	6300	6300
Armature copper drop	0	4.9	9.9	14.8	19.8	24.7
Total induced volts	6300	6305	6310	6315	6320	6325
Core loss	39.4	39.5	39.6	39.7	39.8	39.9
Field copper loss	4.68	5.24	5.92	6.98	8.13	9.92
Armature copper loss	0	0.42	1.08	3.78	6.72	10.51
Friction and windage	30.25	30.25	30.25	30.25	30.25	30.25
Total losses	74.33	75.41	77.45	80.71	84.90	90.58
K.v.a. output	0	534	1071	1604	2140	2672
Real kw. output	0	427	857	1283	1712	2137
Real kw. input	74.33	502.4	934.4	1363.7	1796.9	2227.6
Efficiency	0	85	91.7	94.1	95.3	95.9

After the machine has been running the required length of time, the power-supply circuit should be opened and the field excitation of the machine under test reduced to one-half of the test value, until the machine comes to rest, when the field circuit must be immediately opened. High speed machines with heavy revolving parts should be stopped as quickly as possible; this can be done by using the belted driving motor as a generator with separately excited field, and loading it on resistance racks. The method of shutting down and the time required should be recorded.

When the machine has come to rest additional thermometers must be placed on the different parts and packed with warm waste so as to determine the highest temperatures of the armature iron, armature winding, field winding, pole tips, dampers, bearings (if parts of the machine), and collector rings. Additional thermometers should be placed on or in any other part of the machine which may appear to be hot.

Hot resistances are taken on the armature winding and the field winding. The hot field resistance is that obtained from the last reading of field amperes and volts taken during the temperature tests.

METHODS OF LOADING

Methods of loading alternating-current generators and synchronous motors may be divided into two classes, namely, with the machine running under actual power load of the desired characteristics, and with the machine running under a compromise load approximating the actual load conditions.

Actual Load Method—The machine is belted or coupled to a direct-current generator capable of carrying 50 percent over-load on the tested machine, care being taken before connecting that the normal speed on the latter does not cause the driving motor to exceed its normal speed more than 15 percent. The connections are as indicated in Fig. 2; after they have been carefully checked the machines are started, bringing the tested machine to the desired speed. The generator field circuit is then closed and the excitation gradually increased until normal voltage is obtained without load. The field circuit is then opened, a small resistance load is applied to each phase and after closing the field circuit the voltage is again gradually brought up to normal. This procedure serves as a check on the connections and gives an opportunity for a preliminary mechanical inspection of the rotating parts and bearings. The load is then adjusted to the desired value on each phase, care being taken that the current in each phase is within one percent of the average current of all phases. In place of a resistance load it is frequently preferable to load the generator with an induction motor, or, if the power-factor must be kept at a certain value, with a synchronous motor which is carrying either a uniform mechanical load or driving a loaded direct-current generator. This method gives a balanced load on each phase and admits of any desired adjustment of power-factor values, both of which are difficult of obtainment with a resistance load.

In place of artificially loading the machine, it is sometimes possible to connect it in parallel with another generator or with bus-bars which are carrying an actual commercial load. If the load thus secured is sufficiently well balanced and not too fluctuating, this avoids wasting power. Any desired power-factor or load on the machine may be obtained by suitably adjusting the fields.

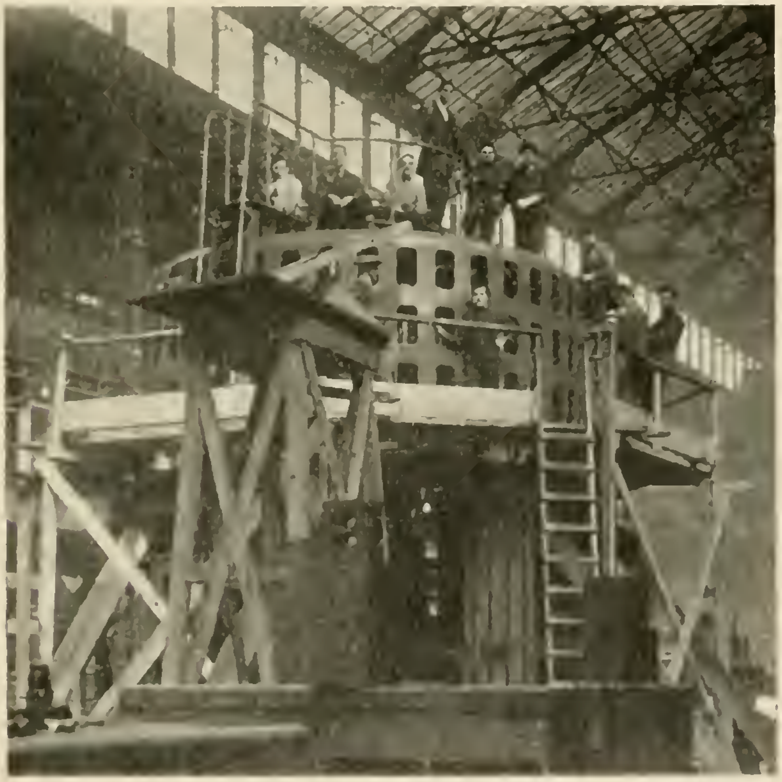

FIG. 1—TEMPORARY CONSTRUCTION ABOUT A LARGE VERTICAL SYNCHRONOUS GENERATOR

Showing method of setting up for test.

Loading Back Method—Actual loading of machines of considerable size for test purposes is usually impracticable on account of the large amounts of power required and the cost of such a procedure. The loading back method, however, secures an actual load upon the machines, yet draws from the source of energy only sufficient power to supply the losses of the machines involved. For this method two alternating-current generators or synchronous motors of approximately similar characteristics are required, which must be so connected that the generator drives the motor electrically, while the motor drives the generator mechanically, the power used for supplying the losses of both machines being taken from the line by the motor.

The mechanical connection may be made by coupling or by belt, or any suitable method whereby the machines may be operated in synchronism. For test purposes it is most convenient to couple or belt each alternating-current machine to a direct-current machine so that the alternator under test is driven by a direct-current motor. This alternator then furnishes power to operate the second synchronous machine as a motor, which in turn drives the second direct-current machine mechanically as a generator. The latter is paralleled with the direct-current line, thus returning most of the power which would otherwise be taken from the direct-current source. As a result of such a closed cycle of operation, all four machines are operated under actual load conditions, with a minimum power consumption, the direct-current motor taking from the line only sufficient power to supply the losses of all four machines. The same result may be obtained by introducing power at the alternating-current motor. The connections for supplying the power to the synchronous motor of a motor-generator set are the same as those described for testing a direct-current generator* under similar conditions. The connections for supplying the power to the direct-current motor with the machines belted together are given in Fig. 3.

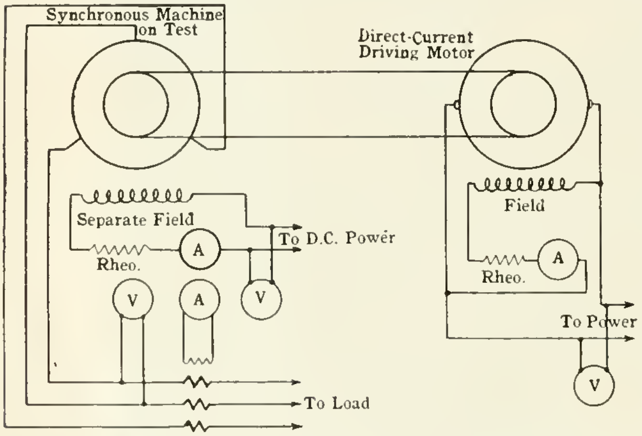

FIG. 2—METHOD OF APPLYING AN ACTUAL POWER LOAD TO A SYNCHRONOUS MACHINE

The sets are started up from either the alternating or direct-current ends, as is most convenient, and synchronized; or one of the sets may be started up first, and the other set then started from the alternating-current side, using power from the first set; in this way synchronizing is avoided. With the connections as in Fig. 3, the direct-current generator being driven without load, the field of the direct-current motor is adjusted to give the correct alternator speed. Then, with normal alternating voltage, the synchronous motor field is adjusted for minimum armature current. The direct-current generator is then paralleled with the line which is supplying power to the direct-current motor, and its field current is increased sufficiently to cause it to take a load, thus increasing the load on all the other machines. If but one machine is under test, the load should be increased until this machine is carrying its rated kilovolt-amperes; if a motor-generator set is being tested as a unit, the load on the direct-current generator of the set should be held correct. This will require adjustment of the fields of both direct-current machines to maintain the load and the speed correct. After the required load has been obtained, the fields of the alternators are adjusted to give the specified power-factor.

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*See the Journal for June, 1913, Fig. 8, p. 609.

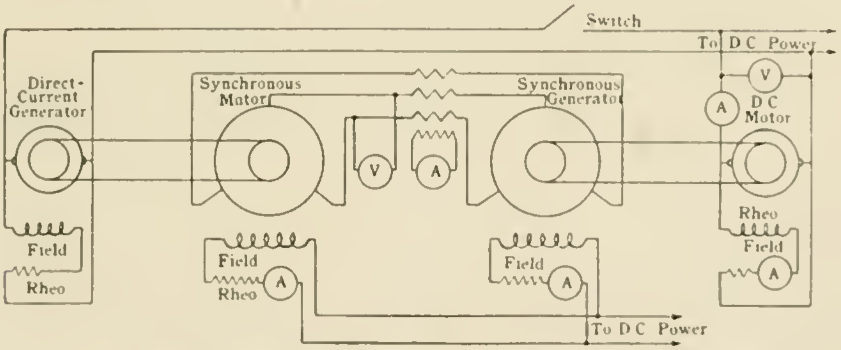

FIG. 3—CONNECTION USED IN THE LOADING BACK METHOD FOR ALTERNATORS USING DIRECT-CURRENT MACHINES

COMPROMISE LOADS

Where an actual load is impossible, some method of loading must be obtained which will approximate the actual load conditions as closely as possible, while at the same time requiring only sufficient power from an outside circuit to supply the losses in the machine or machines used in the test. As these methods usually do not give exactly the same conditions of heating as does normal load on the machine, it is essential to know the kind of deviation from normal conditions and its approximate amount, in order to judge if the method be sufficiently accurate for the purpose at hand, and to make approximate corrections, if desired.

Zero Power-Factor Method at Normal Voltage—Because of its ease of application and accurate approximation to the true operating conditions, this method has been widely adopted for loading alternating-current generators and synchronous motors for temperature determinations. It has been proven experimentally and mathematically that on account of the increased iron losses at low power-factors, the heating effect at 110 percent normal armature current, normal voltage and approximately zero power-factor is about equivalent to that obtained with 125 percent normal armature current at 70 percent power-factor, 135 percent normal armature current at 80 percent power-factor, or 150 percent normal armature current at 90 percent power-factor, which cover the maximum guaranteed conditions of operation for nearly all belted, coupled and engine type units. The slight error obtaind is on the safe side; i. e., the temperatures secured by this method of loading will be slightly higher than those secured under the specified actual load.

When single machines are to be tested, they are run as synchronous motors from a power supply of similar characteristics, the field windings being over-excited so that the required load current will flow in the armature winding. This load may be secured with either under-excited or over-excited field, and care must be taken that the over-excited value is obtained, as the corrections are based on this condition of operation. When two similar machines are available, it is more convenient to run one from the other, a small motor belted to one of them supplying the losses of both, thus avoiding drawing a heavy, low power-factor current from the generating station. In this case, the field of the machine under test must be over-excited and that of the other, under-excited to obtain the desired condition of operation. The machines are connected for this test as shown in Fig. 6, except that there are no mechanical connections between the two, the driving motor being belted to the one on test only. Before beginning the test, a careful check should be made on all connections and the machines then started by the most convenient method, adjusted to the proper speed and synchronized. The field current of the test machine is adjusted to such a value as will give the desired armature current with normal voltage on the line and readings of speed, field current, volts and amperes on each phase are taken. A power-factor of zero is, of course, not actually obtained, as the power-factor must be high enough to provide for the losses in both machines, but will ordinarily vary from five to twelve percent, and in no case should it exceed 20 percent with machines having normal losses.

An Open Circuit Test is sometimes made to obtain a measure of the temperature of the field coils and armature iron with the machine running at its rated speed and with the field so excited that it would give normal voltage if the machine were actually running under its specified load. The temperature will be approximately correct on the field coils only, since this is the only part which is running under normal conditions. The core loss in the armature will be considerably higher than that obtained under actual load conditions due to the higher terminal voltage. The heating of the armature iron is caused almost entirely by the core loss, since there is no copper loss in the armature to influence the temperature; these temperatures may at times be approximately correct since the increased core loss will compensate for the absence of the copper loss. The machines are connected as in the core-loss and saturation tests, care being taken to insulate the terminals thoroughly, as full voltage is impressed upon them.

Short-Circuit Tests are sometimes made to obtain a measure of the temperature of the armature copper, usually at 125 percent normal full-load armature current. Although the resulting temperatures are not as high as they would be with the core loss of the armature added, a fair approximation to the final temperature of the armature conductors is obtained if the short-circuit is maintained until the temperatures become constant. The temperature gradients over the insulation are, of course, somewhat higher than they would be if the core were heated to its normal value.

Open Circuit and Short-Circuit Tests Alternately for short intervals each, at over-potential and over-load respectively, are sometimes used as an approximation of normal load conditions. If the over-load and over-potential are made such that the increase in the copper loss equals the normal core loss and the increase in core loss equals the normal copper loss, the total amount of heat liberated in the machine will be the same as under normal operating conditions. And if the time intervals during which each type of loss is applied are made proportional to the normal losses, the average distribution of heat will approximate normal. Since, however, in practice it is difficult to change the loads, with any degree of accuracy, at intervals of less than about ten minutes, during which time some parts of the machine will become hotter and other parts cooler than normal, the distribution of temperature will vary at different times, and it is difficult to determine the values which correspond to normal operation. Hence, this method is not ordinarily considered as satisfactory as the zero power-factor method.

Circulating Direct Current in the Armature—For this test the machine is run at full speed with the armature windings so connected with all the armature conductors in series or series-parallel that no voltage is developed across the open ends. The most convenient method of obtaining this result on a three-phase winding, either series or parallel, star connected, is to change to a delta connection. To do this, the star or neutral point must be opened and temporary leads attached so that both ends of each phase are available. It is not necessary to open the various parallels unless the circulating current required is greater than is available from the direct-current supply, in which case the parallels of each phase should be connected in series, with the voltages adding. When the correct windings are properly connected together in series the voltage of each phase will be the vectorial sum of the voltages of all the coils in one phase. To join the various phases in delta, after the parallels have been properly connected, leads from one side of each of two phases are connected together and the voltage between the open ends is read; this should be equal to the voltage of one phase. If it is 1.73 times the voltage of a single phase, one phase must be reversed. One side of the third phase is then connected to one of the open ends of the *V*, and the voltage checked; if it is zero, the connections are properly made. If it is double that of one phase, the phase last connected should be reversed. The voltage across the two remaining open ends of the delta may sometimes show a comparatively high voltage, but if the other connections have been properly made this will usually be caused by leakage. To check this a small fuse is placed across the open ends with the field circuit open, and the field current then gradually increased; if the fuse does not burn out the connections are assumed to be properly made. There may also be a voltage across the open ends due to the presence of the higher harmonics or irregularities of design, and at times the current flowing in the closed delta may even equal the normal load current, which will cause the fuse to burn out, even though the connections are correct. In this case some other method of loading should be chosen.

To correct a two-phase machine so there will be zero voltage across the open ends, it is necessary to divide each phase into two parts, connect these so that the voltages are opposed and then connect the two phases in series. The same arrangement applies to the halves of a single-phase winding. The winding of any stationary armature can be connected temporarily so that this test can be made, although it may mean a considerable expense on account of the changes required in the armature connections.

The value of the armature current to be circulated in the open armature must be equal to the normal current in the winding at the specified load. This can be calculated as follows:—for three-phase star connection, the amperes per phase equal the rated volt-amperes, divided by 1.73 times the rated volts; for three-phase delta connection, the amperes per phase equal the rated volt-amperes divided by three times the rated volts; for two-phase, the amperes per phase equal the rated volt-amperes divided by twice the rated volts; for single-phase, of course, the amperes per phase equal the rated volt-amperes divided by rated volts.

The normal voltage of one phase of the machine after being reconnected will be the result of the changes within the winding itself. For three-phase star-connected machines, the voltage will necessarily be the delta voltage of the machine corrected for the number of groups in the original connection changed from parallel to series, or vice versa. For single or two-phase machines the voltage will be one-half the original voltage corrected for the number of groups changed from parallel to series, or vice versa. The voltage across each phase of the reconnected armature should be read and recorded.

Since the direct current in the armature produces a constant magnetic field in which the field poles are revolved, this test can be used only on machines with laminated poles and without copper dampers that form a continuous ring about the pole tip of the revolving field. Excessive losses are produced in the pole tips and dampers of other types.

In polyphase machines with delta-connected armatures there is sometimes an internal current circulating through the windings due to harmonics. When the machine is designed for star connection and is then connected in delta for this test, the circulating current, if any, should be measured with normal field on the machine. This should be corrected for as follows:—When the load current is sufficiently low, the total current flowing should be measured with a dynamometer, or an alternating-current ammeter of a type which will give the total effective current. When the load current is too heavy to be measured with an ammeter or dynamometer connected directly in the circuit, a series transformer should be inserted in the armature circuit and the alternating current read when the machine is running with approximately full-load direct current flowing in the armature and with normal field excitation. The correct direct current for the required load is the square root of the difference between the square of the required alternating current per phase and the square of the circulating alternating current flowing, as shown by the reading of the ammeter.

The machines should be run with the field current giving the normal no-load voltage. This will be somewhat lower than the field current required for normal voltage at full load, and the field temperature will necessarily have to be corrected to the full-load values.

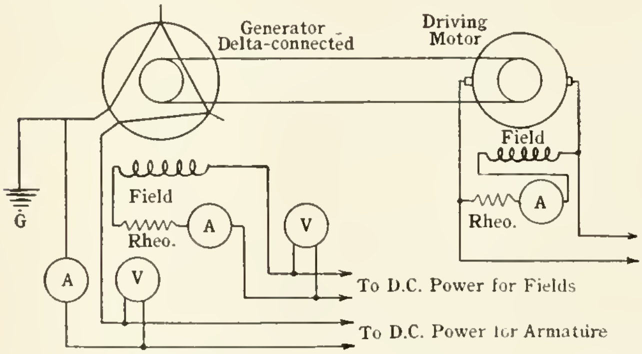

FIG. 4—CONNECTIONS FOR LOADING AN OPEN-DELTA WINDING BY CIRCULATING DIRECT CURRENT

The machines are connected as in Fig. 4 and one side of the open delta is grounded to protect the armature of the direct-current genertor from static strains to ground. The other armature terminals should be carefully insulated from each other and from ground, and especial care should be taken that no one comes in contact with them as there will be full voltage or more between them and ground. After bringing the speed up to normal, the generator field circuit is closed with the armature circuit open, and the excitation is increased to the point where normal voltage is obtained from phase to phase, corrected for the changed conditions. At this point the open delta voltage should be checked. If it is not approximately zero, but nearly equal to double the voltage of one phase, one phase of the open delta should be reversed. The load circuit is then closed and the load adjusted to the desired value, readings being taken of speed, field volts and amperes, armature volts and amperes and circulating currents, if any.

Circulating Alternating Current in the Armatrue—The circulation of alternating current in the armature also closely approximates the actual load conditions. The armature winding is temporarily connected the same as for the circulation of direct current, as in Fig.

4. Current may be obtained either directly from one phase of the machine under test, as in Fig. 5, or from some external source of power, the frequency of which can be controlled exactly. In the second method the frequency of the circulating current must be the same as that of the machine under test, as otherwise there will be a periodic surging of the current, causing vibration of the armature coils which may prove injurious. This condition is extremely difficult to obtain unless the generator supplying the losses is mounted on the same shaft as the machine under test. Consequently, the first method is usually preferable. In this case, however, the load on that phase which supplies the circulating current will be higher or lower than on the other phases and the positions of the thermometers on the armature with reference to the different phases must be noted. On account of this irregular loading, and the extreme difficulty in obtaining suitable voltage ranges on the secondary of the transformer, unless an induction regulator of suitable size is available, which is ordinarily not the case, this method is usually a difficult one to apply. Where the conditions are suitable for the application of this method, however, it gives satisfactory results. The field current must be that which will give normal voltage. This will be approximately the same as the no-load field current and will give the correct armature core loss. The temperature of the fields for the field current required on actual load will be calculated from the temperatures obtained during this test.

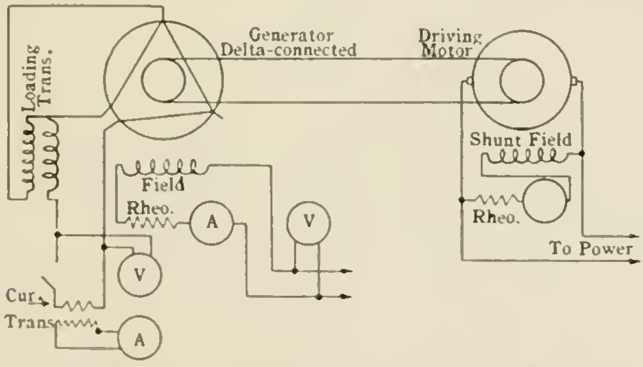

FIG. 5—CONNECTIONS FOR LOADING AN OPEN-DELTA WINDING BY CIRCULATING ALTERNATING CURRENT

Circulating Idle Current by Shifting the Phases—This test can only be made on two similar synchronous machines, which are connected together by means of an adjustable coupling and driven by a separate driving motor capable of supplying the losses of both machines. Current is made to circulate between them by shifting their phase relation by means of the coupling. It is possible to circulate the load at any desired power-factor. The correct conditions are secured by the cut and try method and, therefore, because of the time required to get this adjustment and the necessity of having two similar machines, this method is seldom used. The results obtained, however, are very satisfactory, as the machines are operated under actual load conditions.

The machines are connected as in Fig. 6, using suitable series transformers, and are then started and brought to synchronous speed. With the switches open between the machines their voltages are adjusted until they are equal, and the voltage between them is then read. If this voltage is less than one-third of the terminal voltage, the fields of the two machines are opened and the line switches closed between them. The fields are then gradually excited, with close attention to the line ammeter. If the load current is not correct at the rated voltage, the machines should be shut down and the stator or rotor of one machine should be rotated sufficiently to set the two into the correct phase relation. For slight changes this can be done by means of liners under the feet, but for any appreciable change it should be done by means of the coupling. The phase angle between the machines should be increased or diminished according as the current is too low or too high respectively and in all such changes care should be taken to maintain the air-gap uniform.

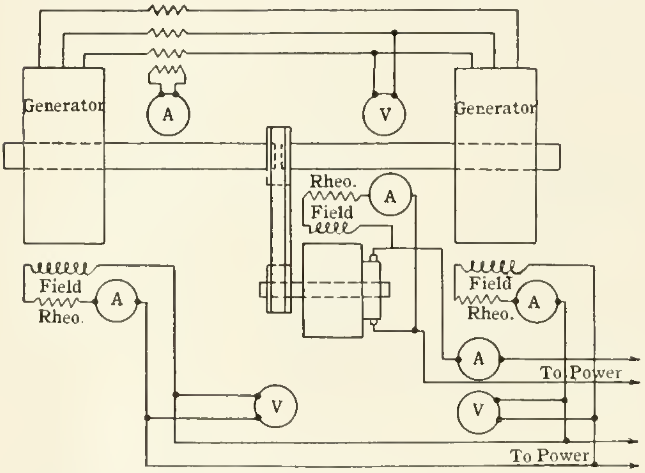

FIG. 6—CONNECTIONS USED WITH LOADING OF ALTERNATORS BY SHIFTING THE PHASE ANGLE BETWEEN THEM

PHASING-OUT ALTERNATING-CURRENT GENERATORS AND SYNCHRONOUS MOTORS

When it is desired to parallel a machine with the line or another machine, it is necessary to have the voltage, the frequency and the rotation of the phases of the incoming machine, the same as that of the line. A voltmeter, and a transformer if necessary, are used to check out the voltage, while to determine the correct phase relations and frequency, lamps, and if necessary transformers, are placed across the paralleling switches.*

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*For a complete discussion of various methods of phasing out polyphase circuits, see the article on this subject in the JOURNAL for May, 1912, p. 437. For a discussion of various connections and methods for synchronizing polyphase machines, see the article in the JOURNAL for July, 1912, p. 634.

Phasing Out Frequency Changer Sets—Frequency-changer sets, consisting of an alternator driven by a synchronous motor of different frequency, mounted on the same shaft, must be paralleled in such a manner that the center lines of the poles of both motors and both generators will occupy the same relative positions simultaneously. This means that there is only one position of the field coils in the complete circumference of the machines at which a frequency-changing set may be synchronized with another similar set. To facilitate phasing, they are frequently designed with the so-called "cradle type" of frame, such as indicated in Fig. 7. This consists of a frame of practically the ordinary shape, but having the frame and the feet cast separately, and machined so that the frame can be adjusted circumferentially within the feet to any desired point by means of screws, the two being bolted together when the desired adjustments have been made.

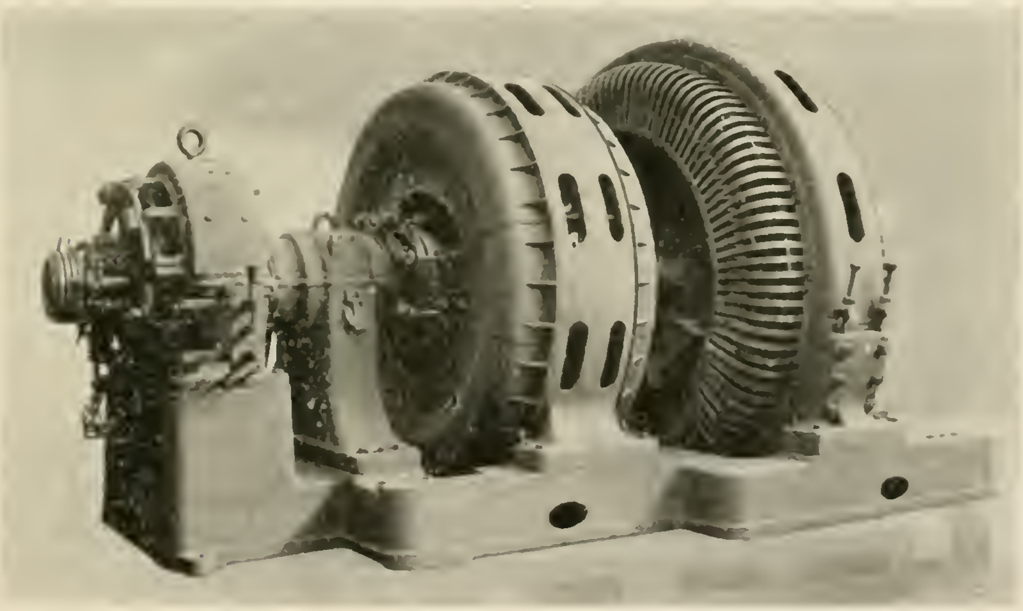

FIG. 7—A TYPICAL FREQUENCY-CHANGER SET

Showing the method of phase adjustment by the use of a "cradle" frame.

In phasing out machines of this type, the two motors are first phased out and operated in parallel from the same supply source. The connections for phasing out the generators are then the same as for any phasing out operation. Since the machines are operating in synchronism, however, there will be no fluctuating of the voltage, but if the machines are out of phase the lamps will burn at a uniform brightness, which will be below normal for all positions except that where the machines are exactly 180 degrees out of phase. To obtain the correct phase relations, it is necessary to rotate the stator of the generator about its center until the voltage across the open terminals, or across the lamps of the phasing-out set, becomes zero. For a final adjustment, it is advisable to replace the lamps with voltmeters and adjust the position of the generator stator until the voltage across the open pairs of leads is approximately zero. The field circuits of the two machines are then opened and the machines are connected in parallel, when the field circuits are again closed and the voltage gradually increased to normal. If the currents flowing in the leads are very small, the connections and positions of the machines are correct; if the currents are excessive the stator must be rotated slightly until the currents are reduced to a minimum, the ammeter readings being always taken at the same generator voltage.

SPECIAL TESTS

The following tests are taken infrequently and then only when the desired results cannot be obtained by the tests already described:

Core Loss as a Synchronous Motor—This method of obtaining core loss is probably more difficult than any other method on account of the large number of variables. The machine is connected to run as a motor from an alternating-current generator, the fields of both machines being easily controllable. The test is run at rated frequency and minimum armature current or approximately 100 percent power-factor as obtained by field adjustment. The machine should be run idle for a half hour or more in order that a careful mechanical inspection be made, with particular attention to the bearing lubrication and the proper operation of the oil rings. When the friction has become constant, as indicated by a steady ammeter reading, the fields of both machines are opened simultaneously for a moment and at the same time the resistances of the field rheostats are increased. This will give the residual magnetism a chance to die down, so that in taking the test the points will be on the rising curve of field saturation. The fields should be closed again before the motor speed drops sufficiently to cause it to drop out of synchronism, and no meter switches should be opened until the machines have again become exactly synchronized. The excitation is then adjusted to such a value as will give one-half normal voltage with the line switches closed at rated frequency and minimum armature current. Readings are taken of armature volts, watts and amperes per phase, field amperes and speed for six or seven points of voltage in succession up to 35 percent over normal voltage, one reading being taken at the rated value of the machine. There is almost always a certain amount of hunting and power variations and accordingly, extreme care must be taken with all meter readings.

Regulation by Actual Load Test—The voltage regulation may be taken under actual load, where such a load, and a suitable method of driving the alternator are available, by loading the machine to the desired value at the desired power-factor, and at normal voltage and speed. Then, maintaining the speed and field current constant, remove the load. The resulting variation in voltage, divided by the load voltage, equals the regulation.

In commercial testing, it is frequently simpler to take sufficient readings for a curve between field amperes and load at any desired power-factor, with constant voltage and speed. If the test is to be run at 100 percent power-factor the generator must be loaded on a water rheostat, or on resistance racks with another alternating-current generator in parallel to control the power-factor. Resistance racks alone give a power-factor from 96 to 98 percent.

The machines are connected as in Fig. 2 and after all connections have been carefully checked, are started and brought to speed. The field circuit of the generator is then closed and the rheostats adjusted to give normal voltage at no-load. Readings of terminal volts, amperes and watts, field amperes and speed are taken at this point and the load is then set at one-fourth normal, care being taken that it is balanced on all phases. The rheostats are again adjusted to give normal voltage and another complete set of readings is taken. This procedure is continued to 25 percent overload.

When the voltage regulation is to be taken at any power-factor other than 100 percent, it is necessary to use either another alternator or choke coils in parallel or in series with the resistance load used in the previous test, or to obtain the entire load by another alternator which is belted to a direct-current generator. If the latter method is used the energy load can be controlled from the direct-current generator while the inductive component can be obtained by adjusting the field of the alternator running as load. The former method is a little harder to control on account of having to adjust the resistance on each phase with each change of load, and the consequent difficulty of obtaining equal currents on all phases.

Having such a curve, the regulation at any desired load is obtained by subtracting the load voltage from the no-load voltage taken from the no-load saturation curve for the same field current.

The difference divided by the load voltage equals the regulation, for that value of load and power-factor.

Regulation of Synchronous Motors—This test is made to determine the field current required when the motor is running under load at normal voltage and frequency and usually at 100 percent power-factor. The motor is loaded by belting or direct connecting it to a generator, and is connected up as shown in Fig. 1, except that the power is supplied to the alternating-current machine and the load is taken from the direct-current machine. After the machines are started up, the field of the synchronous motor is adjusted to give the desired power-factor at the desired load. Readings of terminal volts, amperes and watts, field amperes and speed are then taken at zero and each quarter load up to 25 percent over-load.

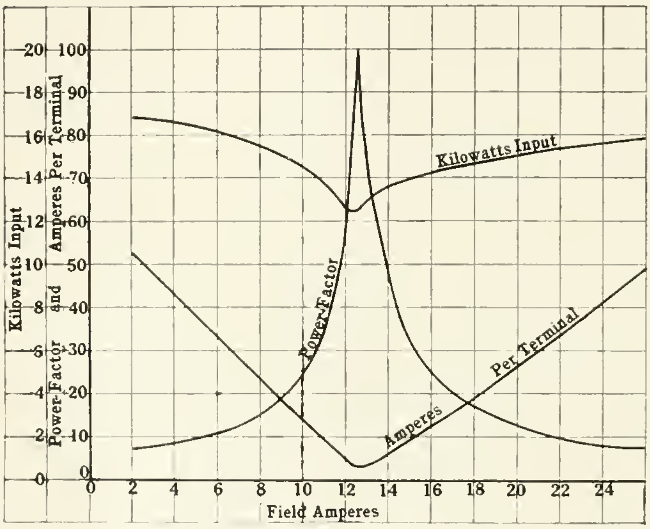

FIG. 8—CHARACTERISTIC CURVES OF A SYNCHRONOUS MACHINE

Showing the effect of field current variation.

Armature Current Characteristics (V-Curve)—This test is made to determine the field current required at any load and power-factor. The machine can be operated either as a motor or as a generator loading entirely on another synchronous machine, or partly on resistance and partly on a synchronous machine. Complete readings must be taken for at least two loads, preferably at no-load and full-load kilowatt output. The limit of armature current should be the same for both tests, the maximum values being such as will give at least 65 percent power-factor both leading and lagging at full-load kilowatt output. About twelve readings are taken at various armature currents over the above range, increasing the field excitation in equal increments from the minimum to the maximum required to obtain the above armature current.

The machines are connected as in Fig. 2, readings being taken at each point, of terminal volts, watts, amperes in each phase, field amperes and speed. The same procedure is followed as already outlined in the regulation test, except that the actual load is held constant and the leading or lagging component is varied by changing the field current of the synchronous machines, the voltage being held constant. A typical set of curves for this test is shown in Fig. 8.

DRYING OUT ALTERNATING-CURRENT GENERATORS AND MOTORS

To make sure that the insulation is in proper condition before being subjected to high voltage, the armature winding of all machines wound for potentials of 3 300 volts and above should be dried out before being placed in service. Machines wound for less than 3 300 volts should also be dried out if they have been exposed to dampness. To satisfactorily dry out the high voltage armature coils used on this class of machines, it is necessary to maintain the entire insulation for a considerable period at a high temperature, which should be kept as nearly uniform as possible throughout the test so that there will be no tendency for the moisture to pass from the hot parts of the coil and condense on the cool parts.

In an open or semi-enclosed machine, which can be independently driven, the best method of drying out is to run the machine with the armature short-circuited and the field excited so that a sufficient current flows through the armature coils to heat them up to the required temperature. When this is done, it is usually found that the armature current required is above the rated full-load value in order that the temperature of the outer layer of insulation may be sufficiently high for satisfactory drying out. This means that the inner layers of insulation have a temperature considerably higher than the outer layers and may be damaged unless their temperature is carefully watched. The temperature of the coils should be taken by thermometers or by resistance coils when possible. As the temperature of the coils will not be uniform throughout their whole length, temperatures should be taken in several different places by thermometers placed between the coils and well packed with waste. The maximum temperature observed, whether obtained by thermometer or resistance coil should be kept at approximately 85 degrees C. throughout the whole drying-out run.

In open type machines which run exceptionally cool, or in which the windage is very great, it may be found difficult to raise the temperature to 85 degrees C. without running an excessive current through the armature conductors; in such cases an attempt should be made to cover up the armature windings or the whole machine with heavy paper, felt or tarpaulin, so as to hinder the cooling of the machine and to facilitate reaching the required temperature and keeping it uniform throughout the whole machine. In a semi-enclosed machine an attempt should be made to stop the natural ventilation and cooling of the machine as much as possible by covering up the inlet and outlet openings. In enclosed machines, such as turbo-generators, the air circulation should be modified so that the outgoing air will pass directly to the intake, and in this manner the same air will keep in continuous circulation, the leakage being sufficient to carry off all the moisture. In some high-speed machines, the air friction alone is sufficient to raise the temperature high enough for drying out, when the natural ventilation is stopped. When this temperature has been reached in such cases, the field should be so excited that about one-third full-load current is circulating in the short-circuited armature, so that the inner layers of insulation will be several degrees hotter than the outer layers.

When the drying-out run is first started the windings should be heated slowly so that the heating will be uniform. When too heavy a current is used the high internal heat will generate gases and vapor which will be forced through the insulation in such a way as to break the continuity of the layers, thus doing considerable damage. It should take from 15 to 20 hours to bring a large machine up to the required temperature.

In machines which cannot be driven independently, the armature can be dried out by connecting all the phases in series and then circulating sufficient direct current through the winding to obtain the desired temperature. After the windings have been heated up for several hours to their maximum temperature, the current should be cut off and the windings allowed to cool down to about 10 or 15 degrees above the surrounding air, then the current should be put on again and the above operation repeated until the desired degree of dryness has been obtained.

The insulation resistance must be taken at regular intervals during the above test and a curve plotted using time as abscissae and resistance as ordinates. This curve will usually show a decreasing resistance as the machine first heats up due to the vaporing of the moisture in the coils. The drying-out test should be continued until the readings show the resistance when hot to be increasing and that there is at least one megohm insulation resistance for each 10 000 volts over-potential test. After this point has been reached the machine must be allowed to cool down to the specified over-load temperature before the over-potential tests are made.

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978—Silver Plating Copper—What is the best method for electroplating silver into copper? Please send me a formula for a solution for cleaning copper, preparation of bath, current density, desired voltage and a method for polishing without using a buffer. I have two searchlight reflectors of silvered copper which have been polished until the silver is worn off in spots. I mechanically cleaned one of the reflectors with silver polish and chemically with a five to one solution of nitric acid, being very careful that no acid remained on the reflector before it was put into the plating bath. The bath was mixed according to the one given for silver plating in Foster's Handbook (potassium cyanide and silver chloride). Current density according to directions given (one ampere to 60 square inches of plating surface) voltage 110. The cyanide seemed to have a chemical action on the copper surface, so that the silver would not stick. The silver surface plated very good and came to a good polish, with using a piece of soft leather. Please advise me how a silver coating can be made to hold on a copper surface?

G. L. H. (IDAHO)

Apparently the surface to be plated was not entirely clean. Surface should be rubbed clean with pumice stone and washed and dipped in a potassium cyanide solution (three ounces per gallon), and then put directly into the plating solution. The entire surface should be wet when removed from water and the water should not come away from any spot as that indicates grease present. If surface is much worn it is often best to clean off all old silver and start on clean brass, but with care this is not essential.

R. P. J.

979—Improving Power-Factor—At the plant with which I am connected, it is desired to improve the power-factor. We have a line about 700 feet long, operating at 440 volts, three-phase, carrying a load of 750 kw at a power-factor of 55 to 65 percent. About one-half of ths load is made up of heating transformers, the rest induction motor load. What would be gained by installing a synchronous condenser at the end of the line, and what size condenser will be required to raise the power-factor to 90 or 100 percent? What is the general allowance of mechanical power output when a synchronous motor is used for power-factor correction, and how much power does it take from a line, for a size suitable for the above conditions and raising the power-factor from 55 to 90 or 100 percent?

A. G. (OHIO)

To increase the power-factor of a load of 750 kw from 55 to 90 percent, would require a synchronous condenser of approximately 705 k.v.a. capacity; to raise the power-factor to 100 percent would require a similar condenser of about 1 200 k.v.a. capacity. The amount of mechanical load that a synchronous motor, over-excited for power-factor correction, may carry is dependent upon its mechanical design, particularly in base, bearings and shaft, and the kind of load to be carried; *i. e.*, whether belted or coupled to the synchronous motor. A synchronous motor used as a condenser should take from the line full rated k.v.a.; the true energy will be only that required for supplying the losses in the machine, which will be roughly, that percentage of its normal rating which is equal to the difference between 100 percent and its full load efficiency; *i. e.*, if the motor has a full-load efficiency of 96 percent, its losses will be approximately four percent, or say, five percent to allow for the fact that the full-load efficiency was probably calculated for 100 percent power-factor, while the condenser operates at approximately zero power-factor. For methods of calculations of this sort, see article in the JOURNAL for October, 1911, entitled, "Power-Factor Correction with Synchronous Condensers," p. 943. The chief thing to be accomplished in a case of this sort is to enable the generator to carry a larger true energy load, and at a better efficiency; the turbine will also work more efficiently and the exciter, switching equipment, transformers, and transmission line will be less heavily loaded, better voltage regulation will be secured and there will be less liability of the motors stalling under load, etc., this latter, and the ability to take on increased load without increase of prime mover and generator equipment, being the predominant features. Whether the installation of a condenser of the proper size would be commercially expedient for this particular installation should be made a matter of special study from the available data. N. S.

980—Three-Phase to Two-Phase Transformation—Can the arrangement shown in Fig. 980 (a) be used to transform from three to two-phase, using a standard 2 200 or 1 100/220 or 110 volt transformers? If so, please give vector diagram and explain.

J. E. K. (PENNA.)

This scheme is not practical, since the phase relations of the two e.m.f's. in phase (a) and phase (b) of the secondary will change with each variation of load. There will also be third harmonic distortions due to the exciting current. Where three transformers are available as shown and there are no 86 percent taps, the most convenient method of obtaining two-phase power is that shown in Fig. 980 (b), in which a small auto-transformer is used to boost the voltage across *A D* 15 percent. See also No. 959. W. M. M'C.

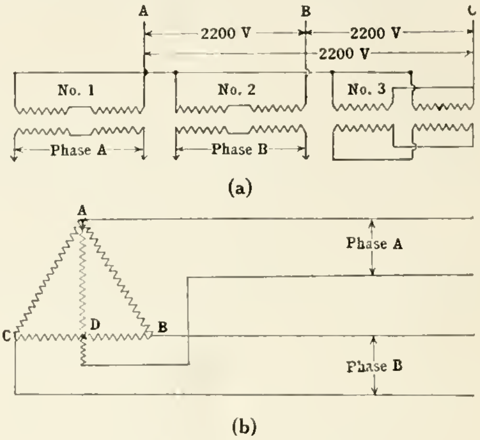

FIG. 980 (a) and (b)

981—Choke Coils for Lightning Protection on Direct-Current Circuits—Low voltage coils, such as are used in telephone work, are provided with an iron core. Choke coils on higher voltages are not provided with an iron core, however, probably due to the transformer action if this were done. A certain installation has a choke coil on a protective panel working in series with a lightning arrester having 50 turns of No. 5 wire and caring for approximately 10 hp on 500 volts direct current. Considerable trouble has been experienced, however, due to line surges when a lightning storm is in the vicinity. Please explain in detail why a choke coil with an iron core would not be allowable on 500 volts direct current and why it is permissable on a lower voltage C.F.B. (WISC.)

Choke coils are, in general, used for two purposes, namely, as a protection against line disturbances on both direct and alternating-current circuits, and to limit the current flow in alternating-current circuits. The high impedance of a choke coil to the passage of electrical disturbances such as surges and lightning discharges is employed to protect apparatus—motors, generators, transformers, etc., which otherwise would probably have the insulation of the terminal winding punctured by an unimpeded discharge coming from the line. The impedance of these coils to the normal current is of little consequence. The equivalent frequency of the class of disturbance against which protection is desired is so high that coils with iron cores are rather less effective than air core coils. This is due to the establishment of currents in the magnetic material that neutralize the action of the coil. Current limiting choke coils are employed to protect apparatus against excessive current rushes such as may occur under short circuit and other conditions of violent overload. These coils may employ iron cores, but usually the conditions make an air core the better design. The disturbances in your instance were probably due to the choke coil acting as a protective impedance and in holding back the surges coming from the line high potentials are developed, which in some way have apparently been a source of trouble to you. The use of iron is not a question of voltage nor of frequency, but of purpose and conditions. K.C.R.

982—Starting Rotary Converters— We have several three-phase, 300 kw. 650 volt railway rotary converters. At present they are started by a direct-current induction motor and then paralleled by the use of lamps. Will it be possible to start them by first exciting the field from the line and then closing the three-phase switch through a reactance or resistance which is afterwards short-circuited? If so, what current would be necessary to bring the machine up to synchronism and would it be necessary to make more than one step to the reactance or resistance, and which would be preferable, reactance or resistance? There is always about 600 volts on the trolley wire which could be used to excite the fields. The machine operates from 650 to 720 volts. Will it be disastrous to change the exciting current from the trolley voltage to the higher machine voltage as the machine is running? The field switch would be arranged to transfer the exciting current from the trolley to the machine terminals, after the main switches were closed and without opening the field circuit.

H. A. D. (NEW YORK)

A rotary converter can be started in this manner taking several times normal k.v.a., but very bad sparking will roughen up the commutator and make the method unsatisfactory. Reactance is preferable to resistance. One step only is required. It would not be disastrous to change the exciting source so long as the circuit is not opened. J. L. Y.

983—Transformer Polarity — One set of three transformers is connected up delta on a three-phase, three-wire system stepping up from 2 300 volts to 13 200 volts, as shown in Fig. 983 (a). We desire to connect another set to run in parallel as shown, and would like to know what the voltage will be from *1* to *4*, *2* to *5*, *3* to *6*, and the cross voltage from *2* to *4*, *1* to *5*, *2* to *6*, *3* to *5*, *3* to *4* and *1* to *6* with all the switches out on the low voltage side of the set marked *A*. The transformers are of the same ratio, and set *B* has a sufficiently light load that the ratio of transformation is not affected thereby. We have a potential transformer of 20 to 1 ratio and a 150 volt voltmeter to use in making tests. Would a comparison of the voltages obtained allow a satisfactory determination of whether the phase relations is correct or not?

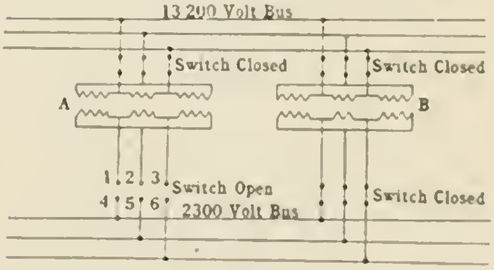

FIG. 983 (a)

L. S. R. (ALA.)

With the connections shown in Fig. 983 (a) voltages from *1* to *4*, *2* to 5 and *3* to *6* should be 0, and the voltages from *1* to 5 or *6*, from *2* to *4* or *6*, and from *3* to *4* or 5 should be 2300 volts if the connections and transformer voltages are correct. If the connections are properly made as shown, but one of the transformers is reversed in polarity inside, there will be a short-circuit on the transformer secondaries at double potential, even before switches *1*, *2* and *3* are closed. If the transformer polarities are correct, but two of the secondary lines are interchanged as shown by the dotted connection in Fig. 983 (a), the potentials will be: *1* to *4*, 0; *2* to *5*, 2300; *3* to *6*, 2300; *2* to *4*, 2300; *1* to *5*, 2300; *2* to *6*, 0; *3* to *5*, 0; *3* to *4*, 2300; *1* to *6*, 2300. From a comparison of readings obtained in the manner suggested it is easy to determine whether the phase relation is correct or not. See also article on this subject by Mr. W. M. McConahey in the JOURNAL for July, 1912, p. 613. C. R. R.

984—Wattmeter Registration—Will a two-element, 400 volt, polyphase watthour meter, connected as in Fig. 984 (a), register four times the actual energy for lighting or just two times?

J. E. K. (NEVADA)

The wattmeter connected as shown in Fig. 984 (a) will register the full current of the lamps, multiplied by 440 volts. In other words, it will register four times the actual wattage of the lamp circuit. C. R. R.

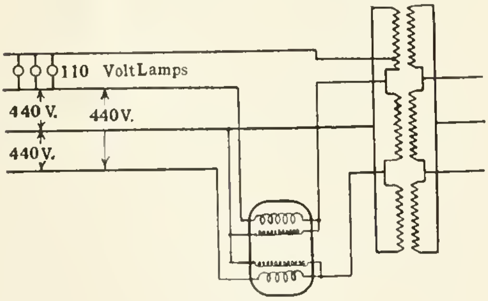

FIG. 984 (a)

985—Testing Oil Circuit Breakers—In testing an electrically operated oil circuit breaker, I get it to close at a lower voltage when I use 220-240 volts direct-current and suitable resistance in series with the coils, than when I use 110-120 volts direct-current and suitable resistance. That is, the circuit breaker will not close at, say, 90 volts obtained in the latter manner, but will close at 90 volts obtained in the former way. I have noticed this more than once, but cannot understand what takes place. The source of supply is a 120-240 volt direct-current generator, three-wire, so that I have either voltage at hand.

J. J. D. (ONTARIO)

The experience wherein electrically operated circuit breakers, when operated at, say, 220 volts, with a considerable resistance in series, close at a lower voltage across the closing coil (as observed after the current has become stable) than when operated at 110 volts with a series resistance, is a matter of common note. At the moment of closing the circuit, the total potential of the circuit appears across the closing coil. This is because no current as yet exists in the circuit and, therefore, no drop, to reduce the line voltage, exists across the resistance. As the current grows, the drop across the resistance develops until a stable condition is attained, but previous to this time a voltage ranging from the total control voltage down to that given by the stable condition has existed across the closing coil. Consequently, with the higher operating voltage the rate of flux establishment for the 220 volt system is far greater than for the 110 volt system. The result of this condition is equivalent to a sudden violent pull in the case of the 220 volt system, which starts the magnet on its way to the closed position. In the case of the 110 volt system the pull is not so abrupt nor intense, consequently the magnet closes in the case of the 220 volt system on apparently lower potential than on the 110 volt system, while, as a matter of fact, it receives at the beginning of the operation, double the potential which occurs in the case of the 110 volt system. K. C. R.

986—Testing Porcelain Insulators—Is it advisable to depend on the voltage test alone in determining whether porcelain insulators are fit for service? For instance, if an insulator is mechanically strong enough for a certain service, and also stands the specified voltage test, ought it to be rejected if it shows signs of being porous, or has cracks which are apparently due to faulty manufacture. Would you take into consideration whether or not the cracks are glazed over? J. J. D. (ONTARIO)

In general, it is not safe to depend on the electrical test alone. The writer has found porcelain that would stand the electrical tests indefinitely with no abnormal manifestation except rapid heating up of the part under stress and an abnormal violet glow. Such porcelain when submerged in water for a few hours, however, broke down by puncture at a very low voltage. It was porous and unsafe to use in a damp place. Some of the following points should be carefully considered in accepting porcelain:—There should be no cracks in the portion subject to electrical or mechanical stress, even if glazed over. Broken porcelain or chips should not absorb over one-half of one percent of moisture when submerged for four days. The required degree of conformity to drawings or general uniformity of the product and also the freedom from blisters and discoloration may be determined by each purchaser acording to his requirements. Three percent variations plus or minus from dimensions is a common limit and many blisters in the glaze are to be looked upon with suspicion. R. P. J.

987—Commutator Trouble—We have a new 10 kw, 110 volt, 4 pole, generator, with 73 commutator bars, which has a spare armature, identical with the original. The armature will run all right for two or three days after the commutator has been turned, but will gradually begin to spark and wear a black spot on the commutator in two places, directly opposite. This starts with a couple of bars and gradually works over to about one-fourth of the commutator. By then the mica has raised so that the generator will not pick up, or if it does, will blaze at the brushes. No amount of shifting of the brushes stops this action and the armature tests clear as far as short-circuits or grounds are concerned. While repairing the commutator, the spare armature ran well for a couple of nights and then went "dead." It had two black spots on the commutator of about 10 bars each on opposite sides. When this commutator was turned up and replaced it acted the same. Kindly state what, in your opinion, would cause this action on the commutator? W. J. L. (ONTARIO)

The trouble indicated may result from several causes, such as operating the generator at overload or under voltage, the latter, providing there is insufficient fringing from the main pole to properly commutate the current in a non-commutating pole type of machine. Faulty brush spacing, poor quality of carbon or loose fit of carbons in boxes, or vibration, due to faulty alignment, may be sufficient to cause initial sparking and blackening of the commutator, which will later lead to high mica. Once high mica is started, sparkless commutation is out of the question, and the blackening of the commutator rapidly spreads through the faulty mechanical contact between commutator and brushes. The armature in question probably has an idle coil, which dissymetry may mark the point of initial blackening of commutator. However, under normal operating conditions it should not explain the trouble experienced. Check the brush spacing carefully, adjusting to practical equality between brushes, install good quality carbons, fitting with clearance in box of not exceeding 0.01 inch in thickness. The brush setting should, in this armature, have forward lead of 1 to 1.125 bars in advance of the geometrical neutral. A thinner carbon may give some improvement, provided the current density does not exceed 40 amperes per square inch. This may be tried by accurately champfering the carbons. If with properly surfaced commutator and rated voltage, the generator still develops trouble, slight undercutting of the mica will probably bring relief. The mica should be cut out clean to a depth of from 1-32 to 1-16 inch. This remedy should not be necessary, however, with a commutator having a low percentage of mica, as in the present case, if operating under conditions of steady and not excessive load at its rated voltage, and where free from inaccuracies of brush spacing and setting, mechanical vibration, etc. A. C. L.

988—Turbo-Rotary Converter Sets, With Rotary Converter Tied In: Exciter Being Direct-Coupled to Alternator—It is usual to excite an alternator from existing direct-current supply during the period of starting up. The rotary converter begins usually to revolve when the turbo-generator reaches one-third to one-half speed. On reaching full voltage and speed the exciter is cut in and the separate excitation is cut out by a make-before-break" switch. (a) Presumably the purpose is to avoid instability of the exciter owing to the heavy currents induced in the generator when it is short-circuited through the rotary? (b) In case of shut down, is it feasible to start up the combination set without relying on separate direct-current excitation? If so, what conditions obtain? If not, why not? (c) Are there any other methods of starting such sets without having an existing direct-current supply available?

P. F. A. (AUSTRALIA)

Turbo-rotary converter sets of 300 and 500 kilowatts capacity have been tested, and no difficulty experienced in starting set, using direct-connected exciter for initial turbo-excitation. The only effect of separately driven excitation during starting is that the necessary turbo voltage for starting the converter is obtained at a lower speed and frequency. Therefore, required voltage is less. Ordinarily, this is of no practical advantage. Converters have even been started by closing intervening switches after turbo has attained normal speed.

F. D. N.

989—Neutral Point of Delta-Connected Generator—Please explain a simple and quick method to determine the neutral point on a three-phase, 2 300 volt, delta-connected turbo-alternator.

A. S. (ARGENTINA)

A delta-connected generator has no neutral point. An artificial neutral may be obtained by the use of delta to star-connected transformers or by the use of interconnected auto-transformers connected as shown in No. 851 or 1006. C. R. R.

990—Transformer Regulation—Please give a formula for calculating transformer regulation at any power-factor, from measurements usually taken in factory tests. Please explain how to determine from tests each factor that enters into the formula. If possible, illustrate use of formula on a three-phase transformer. W. T. (WASH.)

Short-cut formulae, sufficiently accurate for commercial testing are:

To determine the regulation of a transformer when supplying a load at unity power-factor: Percent Reg. = (percent copper drop) + [(percent reactance drop)^2 ÷ 200].

To determine the regulation when transformer is supplying a load at less than unity power-factor: Percent Reg. = (percent copper drop × P-F) + (percent reactance drop × $\sqrt{1-(\text{P-F})^2}$).

The percent copper drop equals the short-circuit loss, divided by the rated output, multiplied by 100. The percent reactive drop equals the square root of (the percent impedance drop squared, minus the percent copper drop squared). The short-circuit loss is obtained by short-circuiting one winding, and applying sufficient voltage to the other winding to produce full rated current, with ammeter, voltmeter, and wattmeter connected in the circuit. The wattmeter reading will indicate the short-circuit loss. The applied voltage, multiplied by 100 and divided by the rated voltage of the winding will be the percent impedance drop. The same rule applies to three-phase transformers, it being understood that three-phase current is used when measuring the short-circuit and impedance voltage, and that the average of the three-phase impedance volts be used in determining the percent impedance drop. When making the short-circuit loss test, it is necessary that the proper frequency be employed, since the reactive drop is directly proportioned to the frequency. See also JOURNAL, Vol.II, p. 361, June, 1905, and No. 781, Oct. '12. W. J. H.

991—Grounding Induction Motor Stator—What causes can be given for the grounding of the stator winding of a 15 hp, three-phase, 220 volt slip ring induction motor, protected by 60 ampere fuses. With a new motor protected by fuses and the installation in good condition, would careless handling of the controller, that is, rapid starting and reversing of the motor before it comes to a full stop cause the stator to ground?

E. B. R. (INDIANA)

Too rapid starting or reversing of the motor might have caused the shocks on coils and insulation which in time causes it to break down. With a well built modern motor this is not liable to happen unless the treatment is exceedingly severe. Nevertheless, instances of this kind occur at times and serve to manifest the importance of giving proper treatment to electrical apparatus.

C. R. R

992—Rotary Converters with Brush Lifting Devices—Why do American manufacturers insist upon the necessity for brush-lifting devices on self-starting interpole rotaries, when European and especially German manufacturers have been supplying these machines for some years without discovering (apparently) that there was any difficulty?

P. F. A. (AUSTRALIA)

Sparking at the brushes in a commutating pole converter during starting may be decreased by designing the converter with a large number of poles, and consequently, low kilowatts per pole, and by placing a short-circuited winding of large cross-section around the commutating pole. There is no question but that American commutating pole converters require the brush lifting device for satisfactory starting. The scheme of short-circuiting the commutating pole winding during starting has been tried, but the damping effect was not sufficient to reduce the sparking to a safe amount in converters designed for 250 kilowatts per pole.

F. D. N.

993—Rotary Converters with Synchronous Boosters—We believe it is usual to make synchronous boosters of a capacity approximately equal to half the desired slip ring voltage variation multiplied by the slip ring amperes, and, for the lower voltage range, using the booster to lower the voltage on the slip rings. Does this not involve reversing the current in the booster field coils, and the use of a potentiometer regulator?

P. F. A. (AUSTRALIA)

With booster type converters the booster has a capacity corresponding to half the desired voltage variation. The booster field current is reversed without opening the field circuit by means of double rheostat. For description and diagram of this rheostat, see the JOURNAL for November, 1908, pp. 621-2.

F. D. N.

994—Separate Excitation of Rotary Converters—Where some direct-current is always available—though possibly with only a small power behind it—would it not be feasible to excite rotary converters from bus-bars, thus ensuring a correct polarity when starting from the alternating-current side (this would also apply to turbo-rotary combined sets run in conjunction with another direct-current plant)? In this case, what is the correct switchgear to use? Obviously a field reversing switch would not be required, but a field discharge switch would apparently be required. Could this be combined with field splitting switch if desired?

P. F. A. (AUSTRALIA)

It is possible to separately excite rotary converters and correct polarity would always be obtained. On railway circuits, however, where short-circuits are common, the separate excitation would be a decided disadvantage on account of the fact that the converter voltage would be held up by the separate excitation. The field reversing switch would not be required. The field discharge switch could be combined with the field break-up switch.

F. D. N.

995—Self-Starting Rotary Converters—Are field splitting switches really required? Why are some makers of interpole rotaries now omitting these switches on quite large sizes of machines?

P. F. A. (AUSTRALIA)

Whether field break-up switches are required depends on the relative turns of armature and shunt field winding. If the break-up switch is omitted, the field winding must be insulated for voltages considerably higher than at present. If the field break-up switch is omitted and the field circuit is carried to the switchboard panel, the necessary insulation of this circuit would be troublesome and the presence of the high voltage dangerous. F. D. N.

996—Turbo-Excitation—Is it usual to place fuses in direct-coupled exciter circuits? State reasons for and against in case of a turbo-rotary combined set, where existing direct-current supply is used to excite the alternator during the period of starting up, and the exciter is cut in after the set has attained full speed. It would appear to be desirable to place fuses in circuit to protect the exciter not only from defects in its own windings or the field windings of the alternator, but from possible disturbances or short-circuits on the back of the switchpanel, or in the breakdown resistance which is usually required to reduce the existing station voltage to the voltage of the excitation circuits. P. F. A. (AUSTRALIA)

In general, it is inadvisable to place fuses or other protective devices in exciter circuits. It is considered better practice to run the risk of damage to the exciter than the certainty of interruption to generator voltage. F. D. N.

997—Meter Readings With Incorrect Ratings—What effect would the following conditions have on the reading of a wattmeter? (a) A single-phase 220 volt circuit is found metered in error by a 110 volt meter; what percent error would one expect to find in the reading? (b) A 60 cycle, two-phase, 1 100 volt circuit is being metered by a 2 200 volt meter, and a 2 200 volt current transformer. Would the reading be approximately halved in such a case? F. G. F. (W. VA.)

(a) A watt-hour meter operating on double voltage would more than probably be burned out in a short time. During its operation, it would probably register less than the correct amount of power, due to the high temperature of the shunt coils and the magnetic saturation of the iron circuits. (b) If suitable constants are provided with the voltage and current transformers, the operation of a watt-hour meter on one-half normal potential would probably be not very much in error, but it would tend to register slightly more than the correct amount of power. The amount of error in either of the above cases would depend considerably upon the type of meter and could not be predicted without knowing the meter characteristics. H. B. T.

998—Generator for Charging Storage Batteries—Please state if it makes any difference what type of generator is used to charge storage batteries. I was told that a compound generator could not be used, since the storage batteries would discharge back through the series field. R. U. (NEW YORK)

A compound-wound generator may be, and often is successfully used to charge storage batteries. There is no danger of the batteries discharging through the series coils unless the terminal voltage of the generator is less than that of the battery, when the battery will discharge through both series and shunt coils. The same condition obtains, however, for a shunt-wound generator. In the case of a compound-wound generator, driven by a motor, the machine may attain a dangerous speed if the motor is disconnected from the power circuit, under which condition the set will be driven by the compound-wound generator acting as a differentially--wound motor, supplied with power from the storage battery. However, the speed depends on the relative strengths of the shunt and series fields. Absolute protection from this condition may be secured by introducing in the generator circuit an automatic circuit breaker with shunt trip coil and reverse curent relay. It is ordinarily considered desirable to charge a battery from a source of supply having a drooping voltage characteristic, as in this case the generator voltage will increase with the battery voltage as the latter becomes charged, and less personal supervision of the charging is required. T. H. S.

999—Electrically Lighted Fountain—One of our consumers is contemplating installing an electrically lighted fountain in his private garden. Please inform us as to where we can find illustrations of installations of this kind; also some information as to how these are built. This consumer is not going in for anything very elaborate.
A. B. M. (NEW YORK)

Such fountains may be lighted by incandescent lamps concealed below glass plates with proper inverted concentrating reflectors. The light may be of various colors and may be controlled by flashers to change the illumination of the fountain from one color to another. The equipment for this purpose may be purchased from any supply jobber handling standard apparatus. The glass plate should be above the surface of the water and the reflectors so placed below the glass plate as to be protected from the water falling on them. This may be done by sealing the glass plate against a cylindrical compartment by means of a good tar or asphalt compound and a felt gasket, or by a litharge—glycerine compound. If the electric fountain is to be studded with various colored lights at the surface of the water, water-proof sockets can be obtained from various manufacturers and the bulbs located partially under the water level. Illustrations of this kind of lighting can be obtained from various publications which show the illumination at the Pan-American Exposition at Buffalo in 1901. A particular example is given in the *Journal of Electricity, Power and Gas* for Oct. 4th, 1913, p. 301.
G. W. R.

1000—Dynamic Braking—What dynamic braking effect would be secured if the primary of a two-phase, 220 volt, squirrel-cage motor be connected to a 110 volt direct-current circuit? If this could be depended upon to stop heavy machinery without shock, it is proposed to use a circuit breaker with over-load and no-load voltage release attachment and another switch is to be connected in series with the no-voltage release coils to shut off the supply to the motors. Is there a device on the market than can be used to connect direct current to the windings automatically after the alternating-current circuit is opened, or is there some form of remote control switch that could be used to better advantage?
R. D. C. (OHIO)

If the primary of an induction motor is excited with direct current and the rotor is rotated, the machine will act as a synchronous generator. The regulation of such a machine is very poor, and the braking effect obtained depends upon having the correct relation between the resistance in the rotor circuit, the speed and the excitation. The continuous voltage required to give full current in the primary circuit will probably not be more than three percent of the normal alternating voltage. If the secondary of the motor is connected across 110 volts, approximately 30 times full-load current will flow, and the motor will be burned out. About 1.25 times full-load current is the practical limit for a braking current which, with the right combination of speed and rotor resistance, will give approximately full-load torque as a maximum. This system of braking cannot be used with all alternating-current motors, due to the large unbalanced magnetic forces, which are liable to cause the rotor to touch the stator. The characteristics of the machine would have to be investigated before a recommendation could be made. Automatic controllers must be arranged to connect the direct-current circuit to the motor after the alternating current is interrupted. In general, a reliable mechanical brake for stopping the motor and driven machinery, is preferable to the use of dynamic braking. See paper by Mr. H. C. Specht, on "Electric Braking of Induction Motors" Proc. of A.I.E.E., May, 1912.
W. S.

1001—Rotary Converter as Synchronous Condenser—(a) Could a 300 kw, 500 volt direct-current, two-phase, 60 cycle rotary converter be used to advantage to improve the power-factor of a 6 000 kilowatt load, the power-factor of this load being 15 percent? (b) Would this rotary converter operate to better advantage for power-factor correction with the direct-current brushes off, that is, run as a synchronous condenser?

W. B. M. (OTTAWA)

(a) Yes; but if it is to be used as a rotary converter, i. e., to supply direct-current load when over-excited, note precautions given in the article by Mr. Nicholas Stahl in the Journal for February, 1912, p. 150. (b) Yes; after starting from the direct-current end and synchronizing, the direct-current side should be disconnected and the brushes raised to reduce friction losses. The machine becomes in effect, a synchronous motor with revolving armature. Sufficient field excitation will then probably be possible to allow the full rated capacity to be used for correcting the power-factor of a 6 000 kilowatt load at 75 percent lagging, to about 77.5 percent. See article in The Journal for October, 1911, p. 943. N. S.

1002—Storage Battery Trays—Kindly let me know the best method for preparing wooden trays and racks that are intended for storage battery installations, so that they will not be destroyed by the electrolyte.

F. J. C. (PENNA.)

The best wooden trays and racks for storage battery installations are made of the highest grade of long leaf yellow pine. The trays are dove-tailed and doweled so that no metal is used in their construction; in the racks the same constuction is used with the exception that several tie bolts are necessary; in both cases the wood is given several coats of paint having an asphaltum base, both before and after assembly for protection against the electrolyte. The use of wooden trays, however, is becoming obsolete, as trays of pressed glass have proven much more serviceable. H. L.

1003—Recharging Permanent Magnets—Please advise if a magnet could be wound for a six volt, 25 ampere current, that would be sufficient for recharging magnets on a magneto used on gas engines. If so, please advise the necessary amount of iron, and size and number of turns of wire.

E. M. (INDIANA)

The design of a magnet to operate on six volts, 25 amperes will depend upon the shape, size and reluctance of the magnets to be treated. To meet the conditions called for, a soft iron core should be made of about the same size as the magneto iron, and wound with as many turns as possible of copper wire; the size of the wire to be such that the total resistance will be 0.24 ohm. The iron should be hammered while the current is flowing. I many cases the winding can be more profitably put directly on the magnet to be magnetized, and the air-gap at the armature end bridged with soft iron. See also No. 438. L. C. W.

1004—Air Circulation for Wood Drying Kiln—What is essential in the way of air circulation for a good wood drying kiln? Take an actual installation in a drying room 75 by 35 by 14 ft. of wood, where no circulation is now had at all. The entire exhaust of a 16 by 36 in., 110 hp, 90 r.p.m. non-condensing engine and also a 2 in. line of live steam is run into coils in the dry room and still no good results are obtained. The lumber usually dried is no thicker than one inch. What would you advise in the way of changes in such a room to get more efficient drying?

F. G. F. (W. VA.)

No possible amount of heat will dry out lumber unless there is an accompanying circulation of air to carry away the moisture. Correct drying of lumber cannot be done rapidly and moist air is frequently circulated through the dry kiln at the same time the temperature is gradaully increased with the idea of drivin all the pitch or tar out of the wood before it is dried, this process involving two or three days' time. By suitably arranging the source of heat, it is usually possible to cause a circulation of the air through the effects of the heaters alone. If this is not possible, some form of fan must be installed. It is impossible to give specific recommendations without knowing the kind of lumber, and the size and arrangement of the kiln.

C. W. D.

1005—Gas Meter—Why is it that a gas meter will register differently for the same amounts of gas (cubic feet) when passed through the meter at different rates? For example, when gas is passing through the meter at the rate of 150 cubic feet per hour, the meter reading may check with the prover reading, but when gas passes through the meter at the rate of, say 30 cubic feet per hour, the meter and prover readings may not check within ten percent. What is the reason? G. N. G. (COLO.)

Assuming that the meter was clean and the working parts not damaged or deranged either from transportation or other causes, and that the meter had not been in service, it should have shown the same degree of accuracy at both flows mentioned, and if it does not, it is quite likely the valves have not been set and timed properly. However, the trouble can be overcome by resetting the valves and making the proper adjustment by the tangent. Of course, if the meter has been in service, there are a number of reasons why it might become inaccurate, such as dirt or other foreign substance on the valves, or a perforated diaphragm or undue friction caused by dirt in the bearings. A. G. H.

1006—Star Connected Auto-Transformers — We have a small three-phase delta wound generator, which is to be used for testing purposes. It is desired to connect it to three star connected auto-transformers as shown in Fig. 1006(b), and to load up between the common point and suitable taps. But, as expected, we are unable to keep the comon point in its neutral position; thus, with a comparatively light load on one phase only, our voltages (between common point and outside of the phases) become respectively 150 percent, 130 percent, and 70 percent of the normal voltage, the voltage of the loaded phase being the lowest. The angular relations between phases become distorted in a similar way. Will you kindly show by vectors or otherwise what causes the common point to change, and which factors determine its position? With the generator delta wound, is there any way of obtaining an absolute or even a reasonable stability of the common point of the transformers?

S. S. H. (MEXICO)

This effect in general is the same as connecting two transformers in series on a single-phase circuit and taking load from one of them, as indicated in Fig. 1006(a), the connections for three-phase being as indicated in Fig. 1006(b). The extent of unbalancing of voltage will depend upon the relative values of the impedances of the three transformers and upon the amount and power-factor of the load. There is no way of obtaining a reasonable stability of the common point of the transformers with ordinary star connected auto-transformers. An auto-transformer may be connected by an inter-connected "Y" connection, as shown in Fig. 1006(c) (see No 851) and the neutral point will be maintained. However, it is much better to use regular transformers and connect them delta-star, in which case the neutral point of the star can be maintained. C. F.

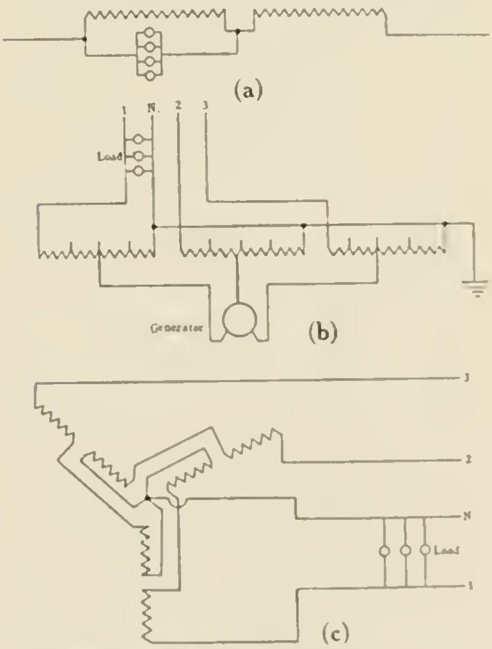

FIG 1006 (a), (b) and (c)

CONTRIBUTORS TO THE JOURNAL FOR 1913

Contributors for whom biographical sketches have already appeared in December issues of previous years are indicated by a (*).

*C. V. Allen, commercial engineer, Compania Ingeniera, Importadora y Contratista, S. A., Mexico City, Mexico.

*C. B. Auel, director of standards, processes and materials, Electric Company.

A. P. Bender (Univ. of Pitts., '06), entered the apprenticeship course of the Electric Company in 1906. In the transformer engineering department, 1908-1911; transformer division of the railway and lighting sales deparment, 1911 to date.

*N. S. Braden, sales manager, Canadian Westinghouse Company, Hamilton, Ont., Canada.

Alan Bright (Carnegie Inst. of Tech., '11), with the Electric Company for a short time. Now illuminating engineer with the Macbeth-Evans Glass Company.

A. W. Burke was educated in England, and after some electrical experiences in South America, joined the Bullock Electric Company; later worked in the shops of the General Electric Company; was then connected with the erection department of the Westinghouse Electric and Mfg. Company until 1906, when he joined the sales department. After four years he organized the Railway and Industrial Engineering Company, and acted as consulting engineer for a number of central stations; is now consulting engineer for the National Properties Company, with headquarters at New York.

A. D. Childs (Princeton Univ., '01) entered the employ of the Cooper-Hewitt Electric Company in May, 1903, first as salesman; later, assistant to the general manager and sales manager.

G. W. Christians, foreman, general testing department, New York Edison Company.

Ira E. Church (Washington State College, '07), after a two years' apprenticeship course at the Electric Company, entered the transformer engineering department; chief electrician of the Potlatch Lumber Company, Elk River, Idaho, 1911 to date.

*C. E. Clewell, electrical engineering department, Sheffield Scientific School, Yale University.

H. W. Cope (Purdue Univ., '98) has been associated with the Electric Company since graduation, in the testing, engineering and commercial departments. In 1905 he was made head of the A. C. correspondence department, and in 1909 assistant to the manager of the industrial and power sales department, of which department he is now assistant manager.

*A. W. Copley, industrial division, engineering department; in charge of development of automobile starting and lighting outfits.

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H. P. Davis (Worcester Polytechnic Inst., '91), vice president, Electric Company, associate editor The Electric Journal.

G. C. Dill (Purdue Univ., '09) spent a short time with the Fairbanks-Morse Company, Indianapolis, Ind.; entered the apprenticeship course of the Electric Company in 1910; since 1912, in the detail and supply engineering department on lighting arresters and protective apparatus.

E. P. Dillon (Univ. of Col., '99), superintendent of transmission with the Telluride Power Company, Telluride, Col., in 1902, after which was engineer with the Colorado Springs Electric Company until 1907, when he was made general manager of the company and of Pike's Peak Hydro-Electric Company; with the Electric Company in the railway and lighting sales department as central station expert, from 1909 to date.

P. H. Donovan, mechanical engineer, Westinghouse Air Brake Company.

*C. W. Drake, commercial engineer on motor applications, industrial and power sales department, Electric Company.

Francis E. Drake received early training as telegraph operator on the Flint & Pere Marquette Railroad, afterwards entering the operating and auditing departments; in 1890 became assistant manager of Sperry Electric Company, and its successor, the Standard Electric Company, of Chicago; in 1897, became assistant manager of Walker Company, Cleveland, from which post he was appointed director of machinery and electricity for the United States at the Paris Exposition of 1900. For his work in this connection, the French government awarded him the Cross of the Legion of Honor. Immediately after the Paris Exposition, he was called upon to reorganize the works of the Union Electricitäts Gesellschaft in Berlin; in 1906, became managing director of the French Westinghouse Company and subsidiary concerns; received advancement to rank of officer in the Legion of Honor in 1910 for distinguished services rendered to French industry; resigned from the French Westinghouse Company in 1911 to devote himself to personal affairs; constructed new tramway system in Palermo in 1912, and acted as general contractor for 30 miles of French State Railways in Algeria. Having been responsible for the construction of the first successful petrol-electric railway motor-cars made by the French Westinghouse Company for Hungarian roads, Mr. Drake founded in 1912 the Drake Railway Automotrice Company, of which he is president and principal owner.

***S. W. Dudley**, assistant chief engineer, Westinghouse Air Brake Company.

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Howard S. Evans, became associated with a prominent Pittsburgh bank in 1892; served in various capacities with the Thomas Evans Glass Company, being secretary of that company when a consolidation took place in 1899, uniting the Thomas Evans Glass Company and the George A. Macbeth Glass Company. Mr. Evans then became secretary of the Macbeth-Evans Glass Company.

S. W. Farnsworth (Worcester Polytech. Inst.) began engineering work at the Underwriters' Laboratories, Chicago, Ill., where he remained until September, 1909, when he came to the Electric Company as high voltage specialist in the transformer engineering department.

A. B. Field (Finsbury Technical College, London, and St. John's College, Cambridge), in 1900, joined the engineering staff of the British Thompson Houston Company and was engaged on the London "tube" railway; later was transferred to the American works of the General Electric Company, at Schenectady; in 1904 joined the Bullock Electric Manufacturing Company, of Cincinnati, having charge of the alternating-current design work until the end of 1908; in 1909 took present position with the Electric Company in the power division of the engineering department.

***B. F. Fisher, Jr.**, commercial engineer, Westinghouse Lamp Company.

F. J. Foley (Pratt. Inst.), after completing the apprenticeship course with the Electric Company, was with the Niagara, Lockport & Ontario Power Company in the high tension operating department; with the Electric Company in the industrial and power sales department on mining applications, 1909 to date.

***C. Fortescue**, transformer division, engineering department, Electric Company.

W. S. Franklin (Univ. of Kansas, '87) took one year of graduate study at the University of Kansas, one year at the University of Berlin, one year at Harvard and two years at Cornell; received the degree D.Sc. from Cornell University in 1901; assistant professor of physics, University of Kansas, 1887-1890; professor of physics and electrical engineering, State College of Iowa, 1892-1897; professor of physics and electrical engineering at Lehigh University, 1897-1903; professor of physics at

Lehigh University, 1903 to date; honorary member, Kansas Academy of Science; past president, Iowa Academy of Science; fellow A. A. A. S. (past chairman, physics section); member American Physical Society; A. I. E. E.; American Mathematical Society; joint author, "Elements of Physics," three Vols.; "Elements of Electrical Engineering," two Vols.; "Dynamos and Motors"; "Electric Lighting"; "Calculus." Has contributed numerous scientific papers to *American Journal of Physics; Physical Review* and *Journal of the Franklin Institute* and to the American Institute of Electrical Engineers.

G. BREWER GRIFFIN, after special commercial law courses in Boston, and business training under the senior partner of Katelle Company, Boston, entered the employ of the Thompson Houston Electric Company, 1889, and occupied successively positions of special finished stock manager, assistant manager of expert department and expert department manager; in 1894, took a position with the Narragansett Electric (Illuminating) Company. Providence, R. I., rebuilding the existing lines and rearranging the transforming and distributing system; in 1895, entered the electrical contracting business to a limited extent; in 1896, took charge of the jobbing, contracting and new business department of the Elmira (N. Y.) Municipal Improvement Company, having to do with general contracting and supply business in connection with street railway, gas and electric lighting, as well as water works plants; in 1900, took a position as special general representative for the Manhattan General Construction Company, and in 1901, established a New England office for them, taking charge of it until this company was taken over by the Westinghouse Electric & Mfg. Company in 1901, at which time he was transferred to the Boston sales office of the latter company; in 1902, was transferred to East Pittsburgh as assistant manager of the detail and supply department, being promoted to present position as manager in 1909.

*DAVID HALL, power division, engineering department, Electric Company.

*H. K. HARDCASTLE, railway division, engineering department, Electric Company.

*F. W. HARRIS, consulting engineer, Los Angeles, California.

*P. N. HARRISON, industrial and power sales department, Electric Company.

*J. M. HIPPLE, engineer in charge, industrial division, engineering department, Electric Company.

SAM'L. G. HIBBEN, (Case School of Applied Science, '10), chief illuminating engineer with Macbeth-Evans Glass Company, Pittsburgh, Pa., 1910 to date.

*FRANCIS HODGKINSON, in charge steam turbine engineering department, Westinghouse Machine Company.

F. L. HUTCHINSON (Cornell Univ., '93); with Westinghouse Electric & Mfg. Co. at Newark, Pittsburgh and New York, 1893-1901; manager publication dept. C. W. Hunt Company, New York, 1901; manager electrical sales dept., National Electric Co., Milwaukee, 1902-3; with American Institute of Electrical Engineers since 1904 (assistant secretary, 1908-11; secretary, 1912 to date).

*R. P. JACKSON, research division, engineering department, Electric Company.

J. L. JONES (Ohio State Univ., '90), worked for three months after graduation with Dr. N. W. Lord, state chemist of Ohio; then was assistant chemist with Junction Iron & Steel Co., Mingo Junction, O. In 1892 became chief chemist of the West Penn Steel Works, Allegheny, Pa., and Leechburg, Pa. From 1893 to 1903 was connected with the ship and engine building firm of William Cramp & Sons, Philadelphia, Pa. While there organized and had charge of the chemical and physical laboratory of that company. From 1903 to date with the Electric Company as metallurgist and chemist for the research engineering department.

W. J. KAUP, on completion of the high school course, took up a study of telegraphy in connection with railroad work, and after an apprenticeship course with the Philadelphia & Reading Railroad, in the machine shops, has held positions as tool maker with the Pennsylvania Diamond Drill & Mfg. Company; draftsman and designer with the same company and general foreman with Philadelphia Lock Company; on completion of mechanical engineering course at Cornell University, accepted a position as mechanical engineer for United States government; since leaving this position, has held positions as inspector of Japanese government locomotives; general superintendent of the H. T. Paiste Electric Company; manager of works, Blair Tool & Machine Company; head of machine construction department at Pratt Institute; present position, manager of works department, Electric Company, in charge of small tool development and design.

B. W. Kerr (Princeton Univ., '06; E.E., Princeton, '08); worked in direct-current section, power division, engineering department, Westinghouse Electric & Mfg. Co., 1908-1910; then in the engineering department of the Pittsburgh Railway Company, until the winter of 1910. Since 1910, with the Railway & Industrial Engineering Co. as assistant manager, and later as manager.

C. W. Kincaid (Univ. of Pitt., '10) entered the student engineering course of the W E. & M. Co directly after graduation; later accepted a position as designing engineer on induction motors and induction regulators, where he is now employed.

*S. M. Kintner, general manager, National Electric Signaling Company, Pittsburgh, Pa.

Morris Knowles (Mass. Inst. of Tech., '91), 1891 to 1893, assistant engineer, East Jersey Company, Patterson, Montclair and Newark, N. J., 1893 to 1897, assistant engineer, Massachusetts State Board of Health and Boston Metropolitan Water Board, investigations for a new water supply for Boston and vicinity; 1897 to 1901, engaged upon investigations for new water supplies for Philadelphia anad New York City and in charge of filtration experiments at Philadelphia; 1901 to 1910, engineer in charge of Bureau of Filtration, Pittsburgh, design and construction of slow sand filtration system and additions and improvements to the water supply system; 1896 to 1900, engineer member, Lawrence, Mass. water board, design and advisory supervision of additional filter at Lawrence in 1907; since 1901 general consulting engineering practice; specialties, waterworks, sewerage and sanitation; since 1908, member of engineering committee of Pittsburgh Flood Commission, making studies concerning flood conditions in the Allegheny and Monongahela river valleys and means of protection and prevention; since 1911, professor and director in charge of department of sanitary engineering, University of Pittsburgh.

C. F. LaCombe, chief engineer, department of water supply, gas and electricity, New York City.

*B G. Lamme, chief engineer, Electric Company, chairman, publication committee, The Electric Journal.

Anton Lederer, general manager and technical director, Westinghouse Mettallfaden Glühlampenfabrik, Vienna, Austria.

*Bernard Lester, commercial engineer in charge of small motor applications, industrial and power sales department, Electric Company.

L. V. Lewis (Cornell Univ., '05), after graduation worked for the Rowland Telegraphic Company; since 1909 with the Union Switch & Signal Company, engaged in the design of alternating-current signaling apparatus and for the past year in the development of automatic train control.

*P. M. Lincoln, general division, engineering department, Electric Company; publication committee, The Electric Journal.

*T. D. Lynch, research division, engineering department, Electric Company.

F. C. Lynch (Univ. of Kansas, '11) entered the employ of the Electric Company in 1911 as student engineer; since January, 1913, in the works management department, in connection with the installation of modern production systems

*J. N. Mahoney, switchboard division, engineering department, Electric Company.

J. E. MATEER (Franklin and Marshall College, '97; two years Penn. State, '99-'01), special apprentice with the Electric Company, Sept. '01, until Oct., '02; then took up work of transformer insulation design, taking full charge of this work in 1906; developed the present line of outlet leads used on outdoor apparatus of high voltage, such as transformers, circuit breakers and lightning arresters.

*W. M. MCCONAHEY, engineer in charge, transformer division, engineering department, Electric Company.

*A. H. MCINTIRE, editor and manager, THE ELECTRIC JOURNAL.

H. F. MCLANE, after leaving high school, took up the study of accounting at the University of Pittsburgh; for the past six years with the Electric Company, first as chief cost clerk in the railway and control division, and for the past two years on the staff of the director of works accounting.

*J. FRANKLIN MEYER, formerly physical engineer, Westinghouse Lamp Company; since July 16, 1913, associate physicist, Bureau of Standards, Washington, D. C.

R. W. E. MOORE (Mass. Inst. of Tech., '04-'06) entered the drafting department of the Electric Company in 1906; later entered the research engineering department where he is now employed.

J. C. MUNN (Denison Univ., '11), for a short period was employed at Hettrick Brothers Company, Toronto, Ohio; in October, 1911, entered the employ of the Electric Company, in the editorial division of the publicity department; in October, 1913, took up work in the advertising department of the *Railway Age-Gazette*.

*WM. NESBIT, New York district office, Electric Company.

*F. D. NEWBURY, engineer in charge, power division, engineering department, Electric Company; associate editor, THE ELECTRIC JOURNAL.

J. A. OLNHAUSEN (Carnegie Inst. of Tech., '08) served a two year apprenticeship course with the Electric Company. Since then in the industrial and power sales division, handling textile applications.

R. S. ORR, (Washington & Jefferson College '91), resigned the position of principal of the Ninth ward school, Allegheny, Pa., in 1904 to become general contract agent of the Allegheny County Light Company. With this company he has later held positions of acting general superintendent, general superintendent and general manager, which is his present position. Mr. Orr is also president of the Pittsburgh Reinforced Pole Company. He is a member of the Eng. Soc. of W. Penna.; The American Electro-Chemical Society and the A. I. E. E. He was president of the Pennsylvania Electrical Association 1911-12; and is now on the executive committee of the Pennsylvania Electrical Association and also of the National Electric Light Association.

*W. F. PATTON, JR., industrial and power sales department, Electric Company.

*J. S. PECK, consulting engineer, British Westinghouse Elec. & Mfg. Company; associate editor, THE ELECTRIC JOURNAL.

*T. S. PERKINS, engineer in charge, detail and supply division, engineering department, Electric Company.

G. PONTECORVO (Univ. of Rome, London Central Technical College) served in the laboratories of Bruce, Peebles & Company, of Edinburgh, Scotland, testing electrical apparatus; with the British Westinghouse Electric & Mfg. Company, Ltd., testing and designing direct and alternating-current apparatus. For the last four years with the Electric Company at East Pittsburgh, as designer of induction motors and on development work on direct-current apparatus.

J. C. POLE, chief engineer, Cooper-Hewitt Electric Company.

*A. G. POPCKE, industrial and power sales department, Electric Company.

*D. C. PULTNEY, manager of works department, Electric Company.

*K. C. RANDALL, engineer in charge, switchboard division, engineering department, Electric Company.

Harry A. Rapelye (Mass. Inst. of Tech., '08) was employed during college course in the gasoline motor department of the Electric Vehicle Company; upon graduation took the position of assistant to the president of Massachusetts Institute of Technology, which he occupied until 1909, when he entered the sales department of the Westinghouse Machine Company; since 1912, commercial engineer with the latter company, in charge of publicity work.

*A. B. Reynders, director of production, Electric Company.

*A. E. Rickards, general manager, Industrial Engineering Company, Pittsburgh, Pa.

*Chas. R. Riker, technical editor, The Electric Journal.

*George W. Roosa, detail and supply sales department, Electric Company.

*B. P. Rowe, switchboard division, engineering department, Electric Company.

*C. H. Sanderson, electrical engineer, Havana Railway, Light & Power Co., Havana, Cuba.

*G. B. Scholl, consulting engineer, Westinghouse Lamp Company.

*Chas. F. Scott, professor of electrical engineering, Sheffield Scientific School, Yale University; associate editor, The Electric Journal.

Wirt S. Scott (Ohio State Univ.) held positions from 1900 to 1908 as assistant in an electrical laboratory and as assistant to a master electrician. From 1908 to 1910 electrical engineer with the McKeever Electric Company, Columbus, Ohio; later general manager of McKeever Engineering & Construction Company; superintendent, Municipal Electric Light and Power Plant, Columbus, Ohio; since 1911, general engineer on power plant installations with the Electric Company.

R. Seybold (Purdue Univ., '07) entered the apprenticeship course of the W. E. & M. Co. in 1907, and on its completion took a position in the railway and lighting sales department in the price division; now head of this division; junior past president, the Westinghouse Club.

*C. E. Skinner, engineer in charge, research division, engineering department, Electric Company, associate editor, The Electric Journal.

Benjamin H. Smith (Sheffield Scientific School, '10), apprenticeship course of the Electric Company, 1910-1912; then entered switchboard engineering division; after a few months at this work, took his present position as engineer on protective relay applications.

E. M. Smith, after a business college course, started as an apprentice in the electrical contracting business; in 1900, he was connected with the New York Telephone Company as inspector of service; in 1902, assumed the same duties with the San Francisco Telephone Company; after two years' service, entered the employ of the Porter-Gribble Company, San Francisco, as manager of the electrical contracting department; in 1906, was made manager of the Oakland branch of the Nernst Lamp Company; manager of the lighting division of the Cleveland office of the Westinghouse Electric & Mfg. Company, 1909-1913; at the present time, general manager, Multi-Lux Illuminating Company, Cleveland, Ohio.

*N. Stahl, commercial engineer in charge, general contract division, railway and lighting sales department, Electric Company.

C. W. Starker (Technical College of Stuttgart, '01), apprenticeship course with the Augsburg-Nuremburg Machine Company, 1901-1902; with the Electric Company, 1902-1903; with the Western Electric Company, 1903-1905; with Electric Company, 1905 to date, in the industrial engineering division of the engineering department, where he has been identified with the development of alternating-current and direct-current industrial motors of the steel frame type.

H. O. Swoboda (Technical High Schools at Dresden, Hanover, Darmsdat and Charlottenburg), connected with Siemens & Halske for two years; came to America in 1892 as electrical engineer with the General Incandescent Arc Light Company of New York; was chief engineer as well as general superintendent during the last few years with this company; from 1899 to 1907, engaged in the manufacture of switchboards, arc lamps and small motors. Took up consulting work at the close of 1907, maintaining an office at New York. During 1909 built and equipped a factory for manufacturing electrical specialties for a supply house in New York City. During 1910 and 1911, assistant section superintendent of the Electric Company; 1912 to date, consulting engineer, Pittsburgh, Pa.

FRANK M. TAIT, after leaving school, served as private secretary and assistant to the president of the Davies & Thomas Company of Catasauqua, Penna.; designed and rebuilt the Catasauqua Electric Light & Power Company and the Catasauqua Gas Company; also the Somerset Lighting Company, covering the entire gas and electric service for Somerville, Raritan and Bond Brook, N. J.; director and manager of the New London Gas & Electric Company of New London, Conn., this company supplying all the gas and electric service, and operating machine shops, boat repairing work, etc., in that district; designed and reconstructed the entire system of the Dayton, Ohio, lighting company, and is now engaged in tying in the outlying cities and towns to the Dayton property; president and general manager of the Dayton Power & Light Company, Dayton, Ohio; the Miami Light, Heat & Power Company, Piqua, Ohio; the Xenia Gas & Electric Company, Xenia, Ohio, and the Wilmington Water & Light Company, Wilmington, Ohio; past president, N. E. L. A.; fellow, A. I. E. E.; member American Gas Institute; member Franklin Institute; member I. E. S.; director Electric Vehicle Association of America.

*W. A. THOMAS, in charge, mining applications, industrial and power sales department, Electric Company.

E. R. TREVERTON (Lehigh Univ., '07), after graduation, was an engineering apprentice at the Denver Gas & Elec. Company until 1908; instructor in the physical laboratory at Lehigh University, and teacher of mathematics and physics at Shippensburg, Pa., high school for two years. Entered apprentice course of the Electric Company; transferred to the illuminating engineering department of the Westinghouse Lamp Company, January, 1911; in charge of this department until August, 1913; at present with the Lighting Engneering Service Co., New York City.

S. TROOD, graduated from the Imperial Technical Schools of Russia, subsequently taking post-graduate work in technology at Vienna, Austria and Zurich, Switzerland, after which he was sent abroad on investigation projects by the Russian government. This work was followed by consulting engineering projects with many of the largest firms in Russia, and at one time he was connected with Kremenetzky-Maeyr Co. and the Schuckert Electric Co., of Vienna. During this period he obtained concessions and built several large trolley lines such as the Ekaterinoslaw Railway; and for the government was active in the investigation and application of electricity to various industries, such as the purification of oils and wax for the candle making industry, and refining processes for the government distilleries, as well as devoting considerable time to the installation of the illumination of several cities in celebration of the coronation of Nicholas II as Czar of Russia; came to the United States in 1902, and in order to learn the language and become acquainted with industrial conditions took a job as day laborer, afterwards occupying positions as tool maker, electrician and superintendent of construction with several New York concerns, eventually organizing and acquiring control of the Trood Realty Company; during this period was occupied incidentally with electrical invention, and after severe business reverses in the panic of 1907 became an independent inventor, devoting his time exclusively to the development of new designs; in 1912, joined the Electric Company at East Pittsburgh as inventor and consulting engineer in electrical and mechanical developments.

*WALTER V. TURNER, chief engineer, Westinghouse Air Brake Company.

HOWARD S. WARREN (Leland, Stanford Univ., '94), after a year in California devoted principally to high tension transmission, joined the engineering staff of the American Bell Telephone Company at Boston in Sept., 1899, where he designed the loading coils used for open wire circuits and for cables; also the phantom circuit repeating coil; in 1903 was placed in charge of the transmission section of the department and in January, 1905, was made head of the equipment division; since 1909, advisory engineer to the American Telephone & Telegraph Company at New York City, on subjects involving the relations of the Bell Telephone system and other interests, such as, interference by induction from power circuits or electrified railroads, physical hazard from high voltage circuits, joint use of poles or conduits, electrolysis protection, Underwriters' rules, committee work, negotiations, contracts, legal cases, etc.

*E. C. Wayne, sales engineer, Goulds Manufacturing Company, Seneca Falls, N. Y.

*Brent Wiley, commercial engineer in charge of steel mill applications, industrial and power sales department, Electric Company.

*C. E. Wilson, industrial engineering department of the Electric Company on design of automobile lighting and starting sets.

*Leonard Work, engineering department, Isthmian Canal Commission.

*J. L. McK. Yardley, power division, engineering department, Electric Company.

CONTRIBUTORS TO THE JOURNAL QUESTION BOX—1913

The following list of contributors who have furnished answers to inquiries published in The Journal Question Box during the present year indicates in a general way the sources from which this information is obtained. This department of the Journal is at the disposal of subscribers as a means of obtaining advice on electrical and mechanical topics. Except where otherwise stated, the contributors are associated with the Electric Company.

V. E. Alden, power division, engineering department.

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R. J. Dearborn, patent attorney, 76 William Street, New York City.

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R. E. Ferris, railway division, engineering department.

S. A. Fletcher, industrial and power division, sales department.

Chas. Fortescue, transformer division, engineering department.

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W. N. Goodwin, Jr., chief electrical engineer, Western Electrical Instrument Company, Newark, N. J.

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J. M. Hipple, engineer in charge, industrial division, engineering department.

A. G. Holmes, manager, the Pittsburgh Meter Company, East Pittsburgh, Pa.

L. F. Howard, chief engineer, Union Switch & Signal Company, Swissvale, Pa.

R. P. Jackson, research division, engineering department.

R. Kelly, power division, engineering department.

C. W. Kincaid, industrial division, engineering department.

A. C. Lanier, industrial division, engineering department.

E. E. Lehr, industrial division, engineering department.

H. Leslie, engineer in charge, operating department, Electric Storage Battery Company, Philadelphia, Pa.

C. G. Lewis, industrial division, engineering department.

P. M. Lincoln, general division, engineering department.

J. N. Mahoney, switchboard division, engineering department.

E. Mattman, power division, engineering department.

R. A. McCarty, power division, engineering department.

W. M. McConahey, engineer in charge, transformer division, engineering department.

W. G. McConnan, service department.

J. W. Miles, foreign division, engineering department.

G. E. Miller, industrial division, engineering department.

R. W. E. Moore, research division, engineering department.

H. C. Nagle, industrial division, engineering department.

F. D. Newbury, engineer in charge, power division, engineering department.

R. H. Newton, power division, engineering department.

J. F. Peters, transformer division, engineering department.

G. Pontecorvo, industrial division, engineering department.

K. C. Randall, engineer in charge, switchboard division, engineering department.

C. R. Riker, technical editor, The Electric Journal.

Geo. W. Roosa, detail and supply division, sales department.

C. H. Sanderson, electrical engineer, Havana Railway, Light & Power Company.

W. Schaake, railway division, engineering department.

O. C. Schoenfeld, industrial division, engineering department.

C. O. Schooley, industrial division, engineering department.

T. H. Schoepf, general division, engineering department.

K. A. Simmons, railway division, engineering department.

C. E. Skinner, engineer in charge, research division, engineering department.

H. C. Specht, industrial division, engineering department.

E. R. Spencer, commercial engineer, Allis-Chalmers Company, Pittsburgh, Pa.

Nicholas Stahl, railway and lighting division, sales department.

E. C. Stone, engineering department, Duquesne Light Company, Pittsburgh, Pa.

Wilfred Sykes, general division, engineering department.

R. H. Taber, power division, engineering department.

H. B. Taylor, detail and supply division, engineering department.

A. A. Tirrill, detail and supply division, engineering department.

Philip Thomas, research division, engineering department.

H. A. Travers, general division, engineering department.

L. Turnbull, railway division, engineering department.

A. F. Van Dyck, research division, engineering department.

H. C. Walter, industrial division, engineering department.

E. C. Wayne, commercial engineer, Goulds Mfg. Company, Seneca Falls, N. Y.

T. Whitehead, general division, engineering department.

W. R. Woodward, detail and supply division, engineering department.

J. L. McK. Yardley, power division, engineering department.

PERSONALS

Mr. George W. Hamilton, who has been consulting engineer with the Pittsburgh-Buffalo Coal Company, of Pittsburgh, Pa., is now in charge of the Chicago sales office of the Milwaukee Locomotive Company, of Milwaukee, Wis., with headquarters in the Railway Exchange Building, Chicago, Ill.

Mr. E. D. Stewart, formerly of the Los Angeles district office of the Westinghouse Electric & Mfg. Company, is now connected with the El Paso office.

Mr. A. J. Reed, of the Dayton office of the Westinghouse Electric & Mfg. Company, has resigned to accept the position of manager of the Cleveland office of the Robbins & Meyers Company, of Springfield, Ohio.

Mr. J. Nadon, recently of the engineering apprenticeship course of the Westinghouse Electric & Mfg. Company, has joined the sales force of the San Francisco district office of the company.

OBITUARY

Mr. Everete Fleet Morse died at his home in Ithaca, N. Y., Noveember 11. Mr. Morse was born at Ithaca, June 28, 1857. He graduated from Cornell University in 1884. In 1893 he patented the Morse rocker-joint chain for bicycles, and in conjunction with his brother, Mr. F. L. Morse, founded the Morse Chain Company and began the manufacture of bicycle chains. The correct mechanical principle embodied in this chain, as well as its novelty, attracted immediate attention and eventually secured for the company a profitable business which lasted until the phenominal slump in the bicycle trade about 1897. In the meantime, Mr. F. L. Morse, who has been the active manager of the Chain Company for the past 13 years, developed the present type of silent chain for power purposes, and during 1906 built the new plant at Ithaca, N. Y., where the business has grown from small beginnings to its present proportions. At the time of his death, Mr. E. F. Morse was a director and secretary of the Chain Company, but for some years past he has devoted himself very largely to his heat guage interests and to various public duties in which he was most active and efficient.

ANGLO-AMDRICAN EXPOSITION, 1914

In London, next year, the people of the United States and Great Britain will get together in an exposition that promises to go far beyond anything of the kind in which they have been interested heretofore. The year 1914 will bring the centenary anniversary of the signing of the treaty of Ghent, which has resulted in one hundred years of peaceful and friendly relation between the two countries, and it is proposed to recognize this anniversary in a way that shall fittingly commemorate its importance as well as illustrate in a definite way just how influential the two countries have been in the material progress of the world. It will be an occasion of joining hands across the sea after a fashion never before attempted, and the scope of the undertaking provides for exhibits that will illustrate what the United States and the United Kingdom have done for the world in the century just closing, in every branch of industry, art, science and education, and will include a historical summary of the progress of the two countries for a century. The site of the exposition, which will be open from May to October, 1914, is the Shepherds' Bush section of London, where have been constructed an imposing group of exhibition buildings. These buildings occupy a tract of more than 150 acres readily accessible from the centre of London's main thoroughfare. The main entrance is connected directly with the terminus of, or in close proximity to, the leading railways, tramways and subway tubes, in the center of a network of transportation lines, affording easy means of communication with all parts of London and all England. Elaborate plans are well under way to make the various exhibits as comprehensive as possible, and a great advantage is the fact that the buildings, all of fireproof construciton throughout, are complete and actually ready for occupancy. This makes impossible the delay and inconvenience some times caused by the inability to finish construction work on time.

American executive offices of the Exposition are in the Woolworth Building, New York City.

The *Electrical Record* for November reprints from the JOURNAL the editorial by Prof. Chas. F. Scott, entitled "Cost and Value of Light."

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NEW BOOKS

"Overhead Electrical Power Transmission"—Alfred Still. 310 pages, 115 illustrations. Published by the McGraw-Hill Book Co. Price, $3.00.

This subject is treated from the standpoint of the office engineer whose duty it is to make calculations and draw up the specifications for the erection of transmission lines. The discussion is limited to straight long distance transmission lines and does not include distribution systems. In chapter three, a discussion is given of the economics of transmission lines including practical costs of various items entering into a preliminary estimate for a new line. A long chapter is devoted to elementary principles and calculations, including the uses of the Marshon diagram. The latter half of the book is devoted to mechanical principles and calculations both of the line and of the line supports. Several appendices are included among them sections on lines with unsymetrically disposed conductors, the effect of the arrangement of conductors, the deflections and stresses in flexible steel towers, specifications for a wooden pole and for a steel tower transmission line.

INTERNATIONAL ELECTRIC CONGRESS

President Mailloux, of the American Institute of Electrical Engineers, announces the appointment of the committee on organization of the International Electrical Congress to be held at the Panama-Pacific Exposition in San Francisco in 1915, as follows: Charles P. Steinmetz, honorary president; E. B. Rosa, honorary secretary; H. G. Stott, chairman; John W. Lieb, Jr., vice chairman; C. O. Mailloux, chairman sub-committee on international relations; A. E. Kennelly, chairman sub-committee on program; H. A. Lardner, chairman sub-committee on Pacific Coast Relations; H. H. Barnes, Jr., chairman sub-committee on transportation; George F. Sever, chairman sub-committee on entertainment; P. S. Millar, secretary-treasurer, and chairman sub-committee on publicity; F. L. Hutchinson, secretary A. I. E. E. (ex-officio).

At the coming convention of the Associated Advertising Clubs of America, to be held in Toronto next June, several desirable prizes are to be awarded to men and to advertising clubs. The greatest and the latest of these is offered for the first time as an annual prize of $1,000 from Advertising & Selling Magazine, to go to the man who has submitted to the Awards Committee of the Associated Clubs the most helpful essay, descriptive article or analysis of some practical phase of advertising or selling. Advertising & Selling makes this offer for the development of sound advertising and sales principles. The gift has the hearty approval of President William Woodhead, of the Associate Clubs. Full details will be sent by Advertising & Selling Magazine, 95 Madison avenue, New York City.

WANTED.

Owing to the duty and heavy freight charges, desire to buy electrical and gas goods of every description under price. Job lots from wholesalers not entirely out of date, would be considered. Write us, giving description and particulars. Enterprise Electric Co., Calgary, Can.

FOR SALE.

Entire stock of goods of live going electrical concern for sale, at a bargain, for $10,000.00 in heart of business district of large western city. A sacrifice price for immediate sale. Established in 1887. A good opportunity for the right man. Address No. 559, care The Electric Journal.

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TEN YEAR TOPICAL INDEX

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Abbreviations:—T-Number of Tables; C-Number of Curves; D-Number of Diagrams; I-Number of Illustrations; W-Number of words; Q.B-Question Box.

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Two-Phase — Three-Phase Transformation Using Standard Transformers—Seth B. Smith and E. C. Stone. Method giving about 90 per cent of rated capacity of units used. D-2, W-300. Vol. VI, p. 441, July, '09.

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